SCIENTIFIC AMERICAN MONTHLY

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SCIENTIFIC AMERICAN MONTHLY
(Successor to Scientific American Supplement)
Edited by A. RUSSELL BOND

Published Monthly by Scientific American Publishing Co. **Munn & Company, 233 Broadway, New York, N. Y.**
Charles Allen Munn, President. Orson D. Munn, Treasurer. Allan C. Hoffman, Secretary, all at 233 Broadway

Scientific American Monthly . . . per year $4.50 **Scientific American (established 1845) . . . per year $5.00**

The combined subscription rates and rates to foreign countries including Canada, will be furnished upon application
Remit by postal or express money order, bank draft or check
(Entered as second class matter, December 15, 1887, at the Post Office at New York, N. Y., under act of March 3, 1879)

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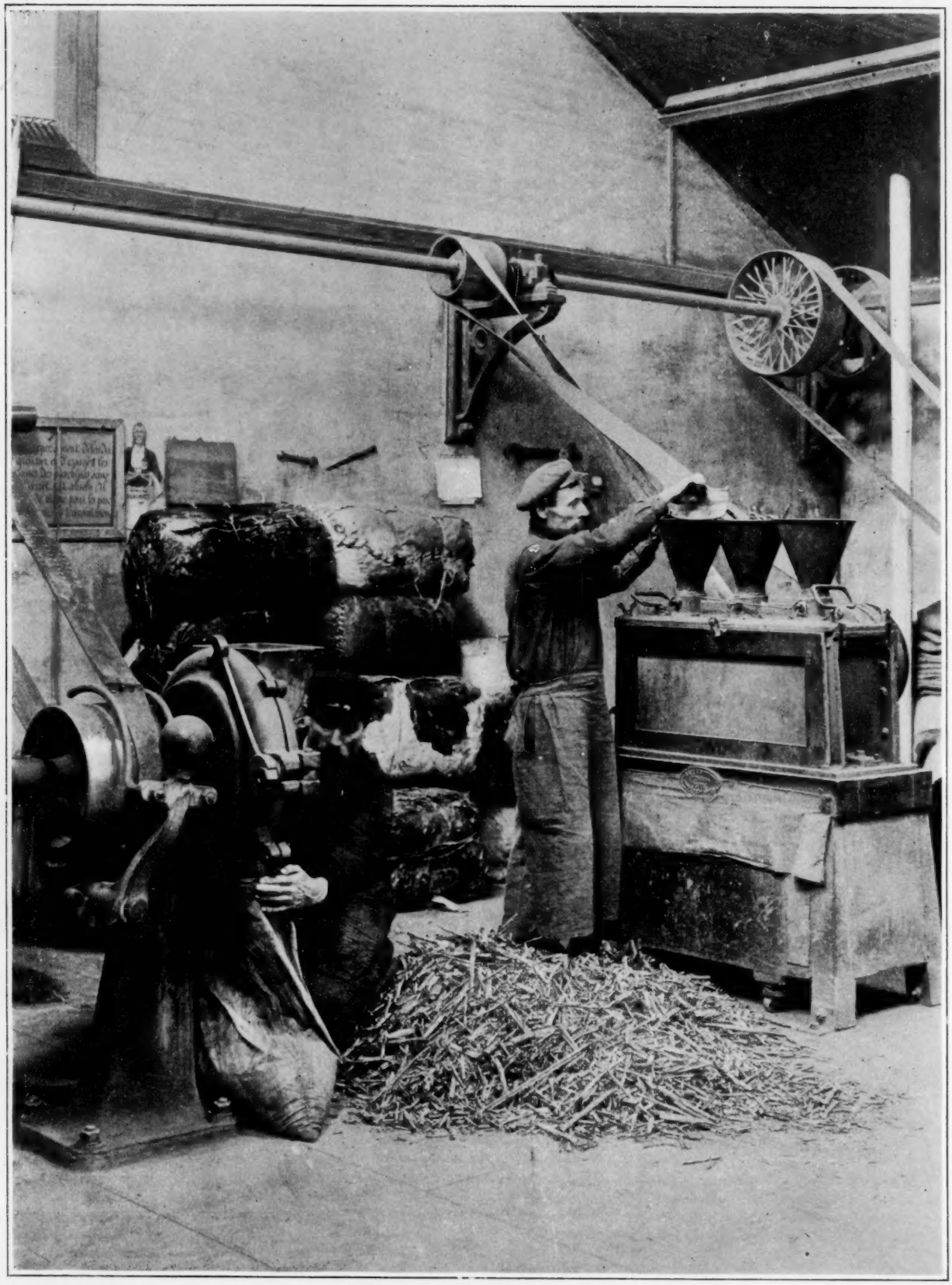


THE ART OF THE APOTHECARY—GRINDING QUINQUINA BARK (SEE PAGE 159).

SCIENTIFIC AMERICAN MONTHLY

VOLUME I
NUMBER 2

NEW YORK, FEBRUARY, 1920

40 CENTS A COPY
$4.50 A YEAR

A ROCKET THAT WILL CARRY TO THE MOON.

THE daily papers, a few weeks ago apprised the public of the fact that Dr. Robert H. Goddard of Clark University, had developed a new form of rocket so far superior to anything now in existence that not only would it carry to the uppermost limits of the earth's atmosphere, but it would actually escape from the earth's attraction. Of course, the newspapers seized upon and featured the statement that the rocket could be fired to the moon.

Had not the announcement of Dr. Goddard's work issued from so reliable a source as the Smithsonian Institution it would not have attracted serious attention. As it was it seriously strained the credulity of the public. Many sober-minded individuals questioned the value of such an attack upon our faithful satellite, and it looked to them like an effort to create a sensation. Some claimed to have found a fallacy in Dr. Goddard's plans. That a rocket could be so improved and refined as to carry to the uppermost reaches of the earth's atmosphere was readily conceded, but to them it was inconceivable that the powder charges could keep on propelling the rocket where there was no air for the gas to act against. Clearly they had a wrong conception of the principle upon which the propulsion of a rocket is based. Had they read Dr. Goddard's complete paper they would have learned that his experiments were conducted *in vacuo* as well as in air and that the velocities obtained *in vacuo* were not much different from those obtained in air. They would also have learned that Dr. Goddard did not begin his research with any Jules Verne idea of a lunar expedition, but solely for the purpose of investigating atmospheric conditions at extreme altitudes. The following quotation from Professor Goddard's paper on the subject show the importance of such an investigation:

"The greatest altitude at which soundings of the atmosphere have been made by balloons, namely, about 20 miles, is but a small fraction of the height to which the atmosphere is supposed to extend. In fact, the most interesting, and in some ways the most important, part of the atmosphere lies in this unexplored region a means of exploring which has, up to the present, not seriously been suggested.

"A few of the more important matters to be investigated in this region are the following: the density, chemical constitution, and temperature of the atmosphere, as well as the height to which it extends. Other problems are the nature of the aurora, and (with apparatus held by gyroscopes in a fixed direction in space) the nature of the α, β, and γ radio-active rays from matter in the sun as well as the ultra-violet spectrum of this body.

"Speculations have been made as to the nature of the upper atmosphere—those by Wegener being, perhaps, the most plausible. By estimating the temperature and percentage composition of the gases present in the atmosphere, Wegener calculates the partial pressures of the constituent gases, and concludes that there are four rather distinct regions or spheres of the atmosphere in which certain gases predominate: the troposphere, in which are the clouds; the stratosphere, predominatingly nitrogen; the hydrogen sphere; and the geocoronium sphere. This highest sphere appears to consist essentially of an element, "geocoronium," a gas undiscovered at the surface of the earth, having a spectrum which is the single aurora line, 557$\mu\mu$, and being 0.4 as heavy as hydrogen. The existence of such a gas is in agreement with Nicholson's theory of the atom, and its investigation would, of course, be a matter of considerable importance to astronomy and physics as well as to meteorology. It is of interest to note that the greatest altitude attained by sounding balloons extends but one-third through the second region, or stratosphere."

The search for some means of raising recording apparatus above an altitude of 20 miles led Professor Goddard to develop a theory of rocket action. The problem was to determine the minimum initial mass of an ideal rocket necessary, in order that on continual loss of mass, a final mass of one pound would remain at any desired altitude. The problem was solved by an approximate method, in order to avoid an unsolved problem in the Calculation of Variations. It was found that surprisingly small initial masses would be necessary provided the gases were ejected from the rocket at high velocity, and also provided that most of the rocket consisted of propellant material, because the velocity enters exponentially in the expression of the initial mass. Thus, if the velocity of the ejected gases be increased five fold, the initial mass necessary to reach a given height will be *reduced to the 5th root*, of that required for the lesser velocity.

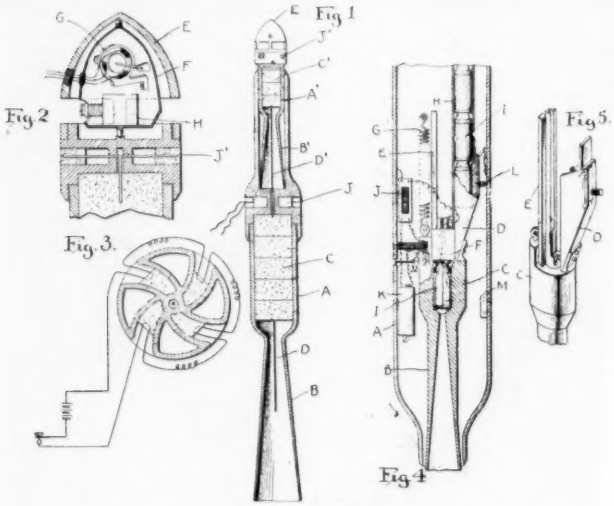
Experiments showed that in an ordinary rocket, the powder constitutes only one-fourth or one-fifth of the total mass and that the average velocity of ejection is about 1,000 feet per second. This is true even of the Coston ship rocket which was found to have a range of a quarter of a mile. The efficiency of the rocket, that is the ratio of the kinetic energy of the expelled gases to the heat energy required, was only two per cent.

In order to increase the velocity of ejection of the gases, charges of smokeless powder were fired in strong steel chambers fitted with tapered nozzles designed to obtain the work of expansion of the gases, as in the De Laval steam turbine. The efficiencies and velocities obtained in this way were remarkably high, the highest efficiency being over 64 per cent, and the average velocity of ejection slightly under 8,000 ft./secs., which exceeds any velocity hitherto attained by

matter in any appreciable amounts. These velocities were proved to be real velocities, and not merely effects due to reaction against the air, by firing the same steel chambers *in vacuo*, and observing the recoil. The velocities obtained in this way were not much different from those obtained in air. It was evident that a heavy steel chamber, such as was used in the experiments, could not compete with the ordinary rocket, even with the high velocities which were obtained.

In order to reduce the weight of the rocket, Dr. Goddard determined to use small charges of explosives fired successively, as in a machine gun, so that the firing chamber would not have to be made of very heavy steel. In this way, most of the mass of the rocket could consist of propellant material,

Several patents have been obtained by Dr. Goddard on his rocket, two of which are illustrated herewith. Figure 1 shows the original design in which the propellant material is contained in mass instead of in separate cartridges. Two rockets are provided, one fitting in the other so that after the



DR. GODDARD'S ROCKET

FIG. 1 to 3, EARLY FORM. FIGS. 4 AND 5, LATEST DESIGN

first has discharged its propellant material, the second will shoot out of it and proceed under its own charge of propellant material. In the figure the main rocket consists of a casing *A* provided with a tapered nozzle *B*. The propellant material is shown at *C* and a fused *D* extends into the nozzle *B*, whereby it may be ignited. At the upper end of the casing *A*, there is an extension in which is fitted the second rocket consisting of casing *A'*, nozzle *B'* and propellant material *C'*. The second rocket is provided with a head *E* which is shown in detail in Figure 2. Within this head is a chamber *F* mounted on pivots to turn freely, and inside this chamber there is a gyroscope *G* which may be actuated by an outside source of electricity to set it in motion at high velocity. Below the gyroscope, there is a recording instrument *H*, which in this case, is shown as a camera. The head *E* is provided with apertures through which the camera or other recording apparatus may have access to the outside.

In order to keep the rocket on its course it must be rotated at high speed, but the camera chamber is kept from rotation by the gyroscope *G*. The rocket is rotated by powder charges in radially spiral chambers as shown more clearly in the sectional view, Figure 3. The rocket is set in a standard fitted with ball-bearings to permit it to revolve freely. Then the charges in the chambers *J* are simultaneously ignited causing the rocket to spin. After sufficient velocity has been obtained the fuse *D* is lighted and the rocket ascends. When the propellant material *C* has all been consumed, the fuse *D'* ignites the propellant material *C'* in the second rocket. The second rocket then shoots out of the first rocket. When the propellant material *C'* is all consumed, fire travels through a fuse to a series of spiral radial chambers *J'*, which are filled with propellant material, and these give further spin to the rocket. Parachute devices are provided to bring the parts down to the ground in safety.

The construction shown in Figure 4 is a later development of Dr. Goddard's rocket. The main casing of the rocket is indicated at *A* and the nozzle *B* leads from the firing chamber *C*. Attached to this chamber *C* at one side is a chute *D* and a pair of guides *E*, which slide in grooves in a breech-block *F*. The construction of the firing chamber is shown in Fig. 5. A spring *G* holds the firing chamber against the breech block. Just above the chute *D* there is a magazine *H* filled with cartridges *I*. One of these cartridges is shown in the firing chamber in our illustration. When this is fired, the chamber *C* is forced downward by reaction against the breech block. and a pin *L* on the chute *D* coming in contact with a cam *M* on the casing *A* releases a new cartridge *I* and lets it slide into the firing chamber. At the same time, mechanism is set in motion to eject the cartridge shell. The cartridges are successively fired by means of battery *K* and spark coil *J*. In a later modification the cartridges are composed almost entirely of a propellant material consisting of an outer shell of compressed smokeless powder covered with a coating of shellac.

Dr. Goddard's experiments showed that it would be possible to raise a mass of one pound to altitudes of 35, 72 and 232 miles by employing initial masses of from 3.6 to 12.6, from 5.1 to 24.3, and from 9.7 to 89.6 pounds, respectively. If a device of the Coston ship rocket type were used instead, the initial masses would be of the order of magnitude of those above raised to the 27th power. Dr. Goddard calls attention to one particular case in which if ship rockets were grouped together in sufficient mass to raise one pound to an altitude of 232 miles, this mass, even neglecting air resistance entirely, would have to be over *six fold greater than the entire mass of the earth.*

As we have stated above, in order to recover the apparatus without damage, a small parachute should be sufficient to insure a safe landing, and Dr. Goddard has obtained a patent upon suitable parachute devices for this purpose. These parachutes would not retard the velocty of the rocket through the tenuous upper starta of the atmosphere, but as denser atmosphere was encountered on the way down the velocity of the falling body would be increasingly retarded until it landed.

Dr. Goddard in his speculations upon the possibility of propelling the rocket to such a distance as to escape the earth's attraction, found that the rocket could start at sea level with a total initial mass of 602 pounds, or from an altitude of 15,000 feet with a mass of 438 pounds, provided the effective velocity was 7,000 ft./sec. and the acceleration 150 ft./sec.^{2}. In order to prove that such an extreme altitude had been reached, he suggests aiming the rocket to strike the dark surface of the moon and providing it with a small mass of flash powder which would be ignited upon impact. He found that a mass of 2.67 pounds of Victor flash powder would be just visible through a telescope of one foot aperture if exploded on the surface of the moon, 220,000 miles distant, and that a mass of 13.82 pounds or less would be strikingly visible. However, as Dr. Goddard says, "this plan of sending a mass of flash powder to the surface of the moon, although a matter of much interest, is not of obvious scientific importance." Calculations show that the total initial mass required to send one pound to the surface of the moon is but slightly less than that required to send it to infinity.

Dr. Goddard's experiments to determine the efficiency of the ordinary rocket and the efficiency of various powders are most interesting. An abstract of that part of his paper which deals with his experimental work is published in the following pages. Mathematical demonstrations and many interesting tables have been omitted owing to limitations of space.

A Method of Reaching Extreme Altitudes*

Experiments with Rockets and Powders

THE following experiments were performed: First, with the object of finding just how inefficient an ordinary rocket is, and secondly, to determine to what extent the efficiency could be increased in a rocket of new design. The term "efficiency" here means the ratio of the kinetic energy of the expelled gases to the heat energy of the powder, the kinetic energy being calculated from the average velocity of ejection, which was obtained indirectly by observations on the *recoil* of the rocket.

EFFICIENCY OF ORDINARY ROCKET.

The average velocity of ejection of the gases expelled from two sizes of ordinary rocket were determined by a ballistic pendulum. The smaller rockets averaged 120 grams, with a powder charge of 23 grams; and the larger, the well-known Coston ship rocket, weighed 640 grams, with a powder charge of 130 grams.

The ballistic pendulum, Fig. 1, was a massive compound

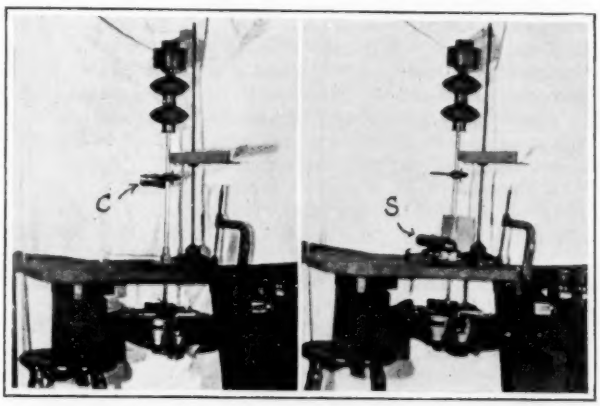


FIG. 1. THE BALLISTIC PENDULUM WITH WHICH THE SMALL ROCKET (C) AND THE LARGE ROCKET (S) WERE TESTED

pendulum, weighing 70.64 Kg. (155 lbs.) with a half period of 4.4 seconds; large compared with the duration of discharge of the rockets. The efficiencies were obtained from the average velocity of ejection of the gases, found by the usual ballistic pendulum method, together with the heat value of the powder of the rockets, obtained by a bomb calorimeter for the writer by a Worcester chemist.

It was found that the efficiency of the ordinary rocket is close to 2 per cent; slightly less for the smaller, and slightly more for the larger, rockets; and also that the average velocity of the ejected gases is of the order of 1,000 ft./sec. It was found by experiment that a Coston ship rocket, lightened to 510 grams by the removal of the red fire, had a range of a quarter of a mile, the highest point of the trajectory being slightly under 490 feet. A range as large as this is rather remarkable in view of the surprisingly small efficiency of this rocket.

EXPERIMENTS IN AIR WITH SMALL STEEL CHAMBERS.

An apparatus was next constructed, with a view to increasing the efficiency, embodying three radical changes, namely, the use of smokeless powder, of much higher heat value than the black powder employed in ordinary rockets; the use of a strong steel chamber, to permit employment of high pressures and the use of a tapered nozzle, similar to a steam turbine nozzle, to make available the work of expansion.

Two sizes of chamber were used, one ½ inch diameter, and one 1 inch diameter. The inside and outside diameters of the smaller chamber Fig. 2 (a), were, respectively, 1.28 cm. and 3.63 cm. The nozzle, polished until very smooth, was of 8 degrees taper, and was adapted to permit the use of two extensions of different lengths. The length of the chamber, as the distance l in the figure will be called, could be altered by putting in or removing cylindrical tempered steel plugs of various lengths, held in place by the breech block.

Two small chambers were used, practically identical in all respects; one of soft tool steel, and one of best selected nickel steel gun barrel stock, treated to give 100,000 lbs. tensile strength. The charge of powder, P, was fired electrically, by a hot wire w.

Two dense smokeless powders were used: Du Pont pistol powder No. 3, a very rapid dense nitrocellulose powder, and "Infallible" shotgun powder, of the Hercules Powder Company. The heat values in all cases were found by bomb calorimeter.[1] All determinations were made in an atmosphere of carbon dioxide, in order to avoid any heat due to the oxygen of the air. The average heat values were the following:

Powder, in ordinary rocket.....	545.0 calories/gm.
Powder, in Coston ship rocket....	528.3
Du Pont Pistol No. 3.....	972.5
"Infallible"	1238.5

The ballistic pendulum used in determining the average velocity of ejection, for the small chambers, consisted essentially of a plank, B, Fig. 3, carrying weights, and supporting the chamber, or gun C, in a horizontal position. This plank was supported by fine steel wires in such a manner that it remained horizontal during motion. In order to make certain that the plank actually was horizontal in all positions, a test was frequently made by mounting a small vertical mirror on the plank, with its plane perpendicular to the axis of the gun, and observing the image of a horizontal object—as a lead pencil—held several feet away while the pendulum was swinging. Current for firing the charge was lead through two drops of mercury to wires on the plank. A record of the

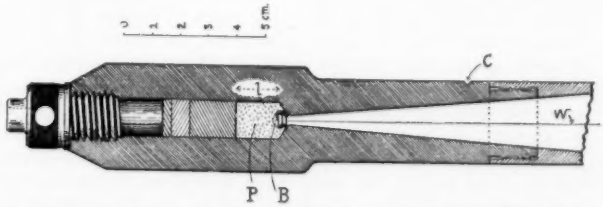


FIG. 2. THE SMALLER CHAMBER IN WHICH POWDERS WERE TESTED

displacements was made by a stylus consisting of a steel rod, S, pointed and hardened at the lower end. This rod slid freely in a vertical brass sleeve, attached to the under side of the plank, and made a mark upon a smoked glass strip, G. In this way the first backward and forward displacements of the pendulum were recorded, and the elimination of friction was thereby made possible.

*Abstracted from a paper by Dr. Robert H. Goddard, *Smithsonian Miscellaneous Collections*, Volume 71, No. 2.

[1]It was found necessary to use a sample exceeding a certain mass, as otherwise the heat value depended upon the mass of the sample.

The highest velocity was obtained with "Infallible" powder, and was over 7,000 ft./sec. The corresponding efficiency was close to 50 per cent. In view of the fact that this velocity is sevenfold greater than for an ordinary rocket, it is easily seen that the employment of a chamber and nozzle such as has just been described must make an enormous reduction in initial mass as compared with that necessary for an ordinary rocket.

As a matter of possible interest, photographs were taken at

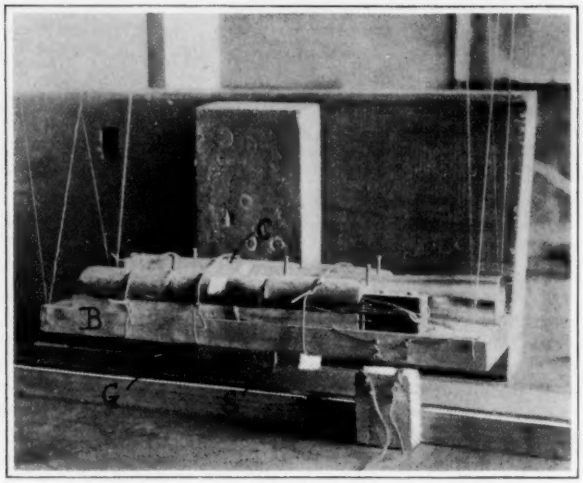


FIG. 3. BALLISTIC PENDULUM FOR DETERMINING AVERAGE VELOCITY OF EJECTION FOR THE SMALLER CHAMBERS

night of the flash which accompanied the explosions produced by firing the small chamber. Two of these are given in Figs. 4 and 5. Fig. 6 shows the set-up for these experiments; the camera being in the same position as when the flashes were photographed. The white marks, above the flash, are strips of cardboard, nailed to a long stick at intervals of 10 cm. and constituting a comparison scale, one end of which was directly above the "muzzle" of the gun. This scale was illuminated, before the charge was fired, by a small electric flash lamp held in front of each strip for a moment; which lamp also illuminated a card bearing the number of the experiment.

The photographs bring out a curious fact, *i. e.*, that the "flash" appears in most instances to be at a considerable distance in front of the nozzle. This is easily understood if we admit that the velocity of the ejected gases is very high just as the gases pass out of the nozzle, but becomes very quickly reduced nearly to zero by the air. In other words we may consider that the gases pass from the nozzle in an extremely short time—for too short to affect the photographic plate; and that it is only when the velocity has been considerably reduced that the "flash" is photographed.

In Fig. 5, a suggestion of this high-velocity portion of the flash is seen, which, it will be noticed, is less in diameter than the end of the nozzle. It should be remarked that it was only by accident that the nozzle was illuminated by the flashes in this experiment in such a way as to be seen in the photograph.

EXPERIMENTS WITH LARGE CHAMBER.

Inasmuch as all the steel chambers employed in the preceding experiments were of the same internal diameter (1.26 cm.), it was considered desirable that at least a few experiments should be performed with a larger chamber, first, in order to be certain that a large chamber is operative; and secondly, to see if such a chamber is not even more efficient than a small chamber. This latter is to be expected for the reason that heat and frictional losses should increase as the *square* of the linear dimensions of the chamber; and hence increase in a less proportion than the mass of powder that can be used with safety, which will vary as the *cube* of the linear dimensions.

The large chamber was of nickel-alloy steel 115,000 lbs. tensile strength. This chamber had inside diameter, and diameter of throat, both twice as large as those of the chambers previously used; but the thickness of wall of the chamber and the taper of the nozzle were, however, the same. The inside of the nozzle was well polished. Fig. 7 shows a section of the chamber; the outer boundary being indicated by dotted lines, *P* being the powder, and *W* the wadding. It will be noticed that the wadding is just twice the size of that previously used.

The mounting of the chamber, for the experiments, is shown in Fig. 9. The chamber was held in the lower end of a 3½-foot length of 2-inch pipe, *P*, by set-screws. Within this pipe, above the chamber, was fastened a length of 2-inch steel shafting, to increase the mass of the movable system. This system was supported by a half-inch steel pin, *E*.

On firing, the recoil lifted the above system vertically upward against gravity, the extent of this lift, or displacement, being recorded by a thin lead pencil, slidable in a brass sleeve set in the pipe at right angles to the pin *E*. The point of the pencil was pressed against a vertical cardboard, *C*, by the action of a small spring. This method of measuring the impulse of the expelled gases will be called the "direct-lift" method.

Although rebound of the gases from the ground would probably have been negligible, such rebound was eliminated by a short plank, *D*, covered with a piece of heavy sheet iron, and supported at an angle of 45° with the horizontal. This served to deflect the gases to one side.

In Experiment 51, with this large chamber, the Du Pont powder used was packed rather loosely. Any increase in internal diameter was inappreciable, certainly under 0.01 mm. In Experiment 52, the Infallible powder used was somewhat compressed. After firing, the chamber was found to be slightly bulged for a short distance around the middle of the powder chamber, the inside diameter being increased from 2.6 cm. to 2.7 cm., and the outside diameter from 5.08 cm. to 5.14 cm. The efficiency (64.53 per cent) in Experiment 51,

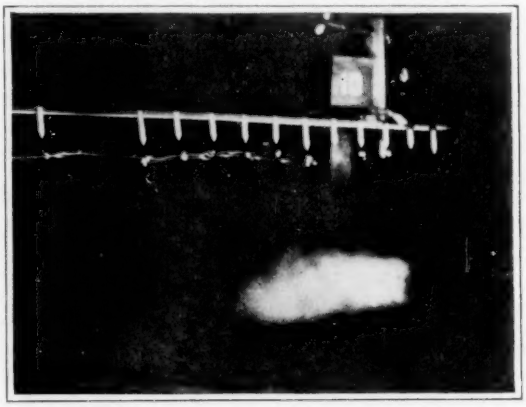


FIG. 4. PHOTOGRAPH OF FLASH FROM THE SMALL CHAMBER

and the velocity (7,987 ft./sec.) in Experiment 52 were, respectively, the highest obtained in any of the experiments.

The conclusions to be drawn from these two experiments are: First, that large chambers can be operated, under proper conditions, without involving undue pressures; and secondly, that large chambers, even with comparatively short nozzles, are more efficient and give higher velocities than small chambers.

It is obvious that large grains of powder should be used

in large chambers if dangerous pressures are to be avoided. The bulging in Experiment 52 is to be explained by the fact that the grains of powder were too small for a chamber of the size under consideration. It is possible, however, that pressures even as great as that developed in Experiment 52 could be employed in practice provided the chamber were of "built-up" construction. A similar result might possibly be had if several shots had been fired, of successively increasing amounts of powder. The result of this would have been a hardening of the wall of the chamber by stretching. Such a phenomenon was observed with the soft steel chamber already described, which was distended by the first few shots of Infallible powder, but thereafter remained unchanged with loads as great as those first used.[2]

EXPERIMENTS IN VACUO.

Having obtained average velocities of ejection up to nearly 8,000 ft./sec. in air, it remained to determine to what extent these represented reaction against the air in the nozzle, or immediately beyond. Although it might be supposed that the reaction due to the air is small, from the fact that the air in the nozzle and immediately beyond is of small mass, it is by no means self-evident that the reaction is zero. For example, when dynamite, lying on an iron plate, is exploded, the particles which constituted the dynamite are moved very rapidly upward, and the reaction to this motion bends the iron plate downward; but reaction of the said particles against the air as they move upward may also play an important rôle in bending the iron. The experiments now to be described were undertaken with the view of finding to what extent, if any, the "velocity in air" was a fictitious velocity. The experiments were performed with the smaller soft tool steel and nickel-steel chambers that have already been described.

METHOD OF SUPPORTING THE CHAMBER IN VACUO.

For the sake of convenience, the chamber, or gun, should evidently be mounted in a vertical position, so that the expelled gases are shot downward, and the chamber is moved upward by the reaction, either being lifted bodily, or suspended by a spring and set in vibration.

The whole suspended system was therefore designed to be contained in a 3-inch steel pipe, all the essential parts being

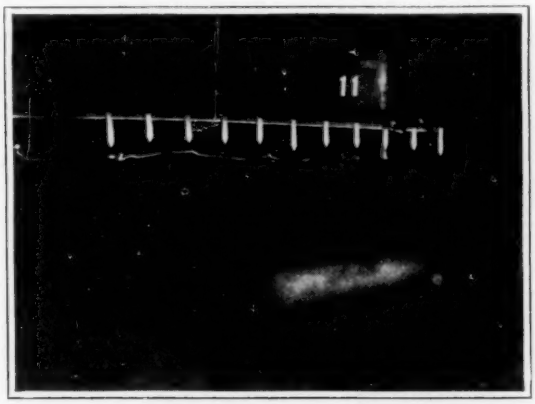


FIG. 5. ANOTHER PHOTOGRAPH OF FLASH. NOTE NOZZLE OF CHAMBER

fastened to a cap, fitting on top of this pipe. This was done not only for the sake of convenience in handling the heavy chamber, but also from the fact that the only joint that would have to be made air-tight for each shot would be at the 3-inch cap.

The means of supporting the chamber from the cap is shown in Figs. 8 and 10. Two 3/8-inch steel rods, *R*, *R*, were threaded tightly by taper (pipe) threads into the cap, *C*. These rods were joined by a yoke, at their lower ends, which served to keep them always parallel. Two collars, or holders, *H* and *H'*, free to slide along the rods *R*, *R*, held the chamber or gun, by three screws in each holder. The inner ends of the screws of the lower holder were made conical, and these fitted into conical depressions, *c*, Fig. 2, drilled in the side of the gun, so that the lower holder could thus be rigidly

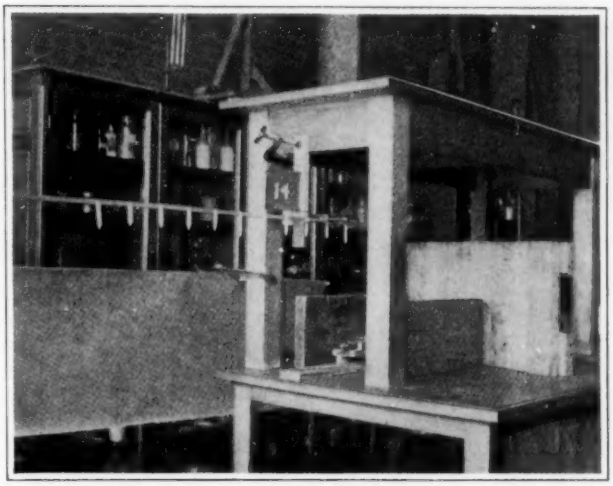


FIG. 6. SET-UP FOR EXPERIMENTS ON THE SMALL CHAMBER

attached to the gun. This was made necessary in order that lead sleeves, fitting the gun and resting upon the lower holder *H'*, could be used to increase the mass of the suspended system. Three such sleeves were used, the two largest being molded around thin steel tubes which closely fitted the gun. The rods *R*, *R*, were lubricated with vaseline. Two 1/8-inch steel pins were driven through the rods *R*, *R*, just above the yoke *Y*, in order that the latter could not be driven off by the fall of the heavy chamber and weights when direct-lift was employed.

In the experiments in which the chamber and lead sleeves were suspended by a spring, the latter was hooked to its upper end to a screw-eye fixed in the cap *C*. The lower end of the spring was hooked through a small cylinder of fiber. A record of the displacements of the suspended system was made by a stylus, *S*, in the upper holder *H*. This stylus was kept pressed against a long narrow strip of smoked glass, *G*, by a spring of fine steel wire. This strip of smoked glass was held between two clamps, fastened to a rod, the upper end of which was secured to the cap *C*, and the lower end to the yoke, *Y*. Except for the largest charges used, it was possible to measure the displacements on both sides of the zero position, and thereby to calculate the decrement and eliminate friction.

When the chamber was suspended by a spring, a deflection as large as a centimeter was unavoidably produced merely by placing the cap *C* on the 3-inch pipe or removing it, although, in all cases the system would return to within one millimeter (usually much less than this) of the zero position after being displaced. In order to avoid any such displacement as that just mentioned, an eccentric clamp *K*, Fig. 10, was employed to keep the suspended system rigidly in its zero position during assembling and dismounting the apparatus.

This clamp consisted of an eccentric rod, *K*, free to turn in a hole in the cap *C*, the lower end being held in a bearing in the yoke *Y*. Through the upper end of this rod was pinned a small rod *K'*, at right angles to *K*. The surface of the rod *K* was smeared with a mixture of bee's wax, resin, and Venice

[2]Since this manuscript was written, rockets with a single charge, constructed along the general lines here explained, have been considerably further developed.

turpentine; and the hole in the cap through which *K* projected was rendered air-tight by wax of the same composition.

The suspended system was assembled while the cap *C* was held by a support touching its under side. When the assembling was complete, the wax was heated by a small alcohol blow torch until it was soft, then a rubber band was slipped around the rod *K'* and the outlet pipe *E*. A trial showed that the cap could now be put in place on the pipe and removed, without moving the suspended system appreciably. After the cap *C* was in position on the pipe, the rubber band was removed, and the wax heated until the rod *K* could be turned out of engagement with the holders *H*, *H'*. After a shot had been fired, the clamp was again placed in operation until the system had been taken from the 3-inch pipe and the smoked glass removed.

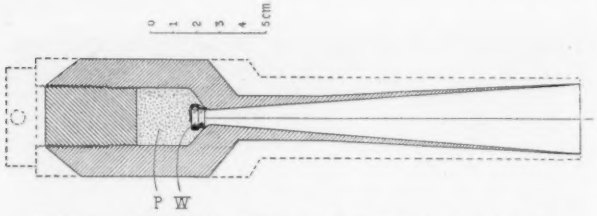


FIG. 7. SECTIONAL VIEW OF THE LARGE CHAMBER

The circuit which carried the electric current to ignite the charge consisted of the insulated wire *W*, which passed through a tapered plug of shellacked hard fiber, in the cap *C*, thence through a glass tube to the yoke *Y*, to which it was fastened. Below the yoke it was wrapped with insulating tape, except at the lower end where it was shaped to hold the 0.24 mm. steel wire, attached to the fine copper wire from the wadding. From the chamber the current passed up the rods *R*, *R* and out of the cap, around which was wrapped a heavy bare copper wire, *V*, which together with *W*, constituted the terminals of the circuit. It should be mentioned, in passing, that a small amount of black powder, *B*, Fig. 2 placed over the platinum fuse-wire on the wadding, was found necessary as a primer in order to ignite dense smokeless powders *in vacuo*.

In order to make the joint, between the cap and the pipe, air-tight during a determination, the following device was adopted. The outside of the cap, *C*, and also a lock nut, were both turned down to the same diameter. The lock nut was made fast to the pipe. These were then painted on the outside with melted wax consisting of equal parts bee's wax and resin with a little Venice turpentine.

When a determination was to be made, the cap was screwed into position, a wide rubber band was slipped over the junction between cap and lock nut, and the outside of this rubber band was heated with an alcohol blast torch. The result was a joint, for all practical purposes, absolutely air tight, which could, nevertheless, be dismounted at once after pulling off the rubber band.

THEORY OF THE EXPERIMENTS IN VACUO.

The expression for the velocity of the expelled gases are easily obtained for the two types of motion of the suspended system that were employed, namely, simple harmonic motion produced by a spring, and direct lift. Results obtained with simple harmonic motion (slightly damped, of course) were naturally more accurate than with direct lift, as it was impossible in the latter case to eliminate friction, but the former could not be used when the powder charges were large.

MEANS OF ELIMINATING GASEOUS REBOUND.

It should be remembered that the real object of the vacuum experiments is to ascertain what the reaction experienced by the chamber would be, if a given charge of powder were fired in the chamber many miles above the earth's surface. A container is therefore necessary, which, for the purpose at hand, approaches most nearly a container of unlimited capacity. A length of 3-inch pipe, closed at the ends, is evidently unsuitable, because the gas, fired from one end, is sure to rebound from the other end with considerable velocity, and hence to produce a much larger displacement than ought really to be observed. Moreover, any tank of fininte size must necessarily produce a finite amount of rebound, from the fact that the whole action is equivalent to liberating suddenly, in the tank, one or two liters of gas at atmospheric pressure.

There are two possible methods for reducing the velocity of the gas sufficiently to produce a negligible rebound: a *disintegration method*, whereby the stream is broken up into many small streams, sent in all directions (*i. e.*, virtually recon-

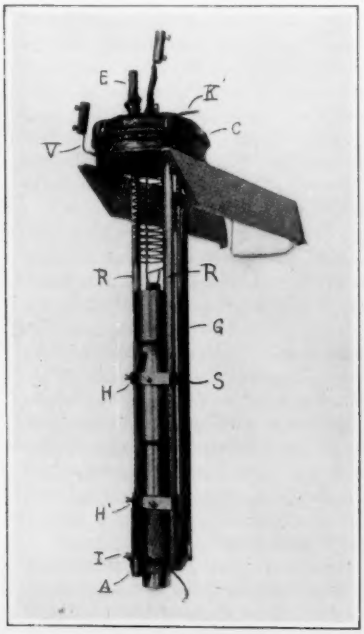


FIG. 8. MEANS OF SUPPORTING THE LARGE CHAMBER

FIG. 9. MOUNTING OF THE LARGE CHAMBER

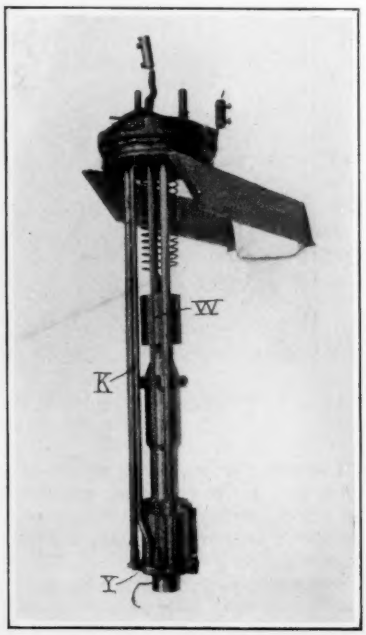


FIG. 10. VIEW OF THE LARGF CHAMBER SHOWING ECCENTRIC CLAMP K

verted into heat); and secondly, a *friction method*, whereby the individual stream remains moving in one direction, but is gradually slowed down by friction against a solid surface.

As will be shown below, accurate results were obtained by the first method, in what may be called the "cylindrical" tank; and these results were checked satisfactorily by the second method, in what will be called the "circular" tank.

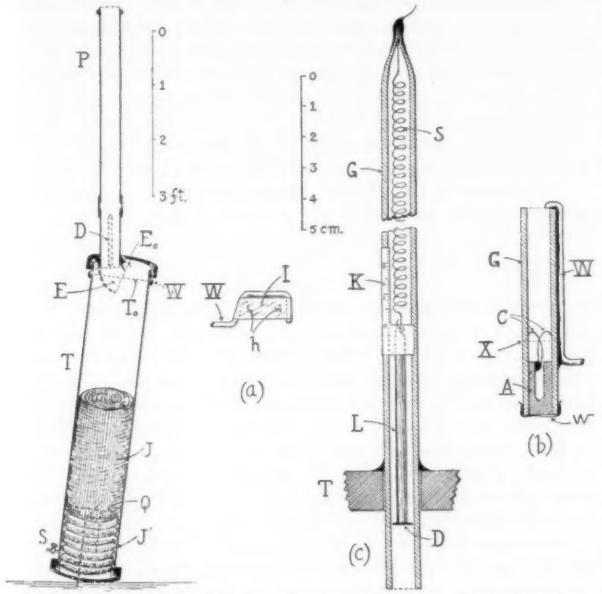


FIG. 11. THE CYLINDRICAL TANK. FIG. 12. THE TISSUE PAPER DETECTOR

The cylindrical tank was 10 feet 5 inches high and weighed about 500 lbs. It consisted of a 6-foot length *T*, Fig. 11, of 12-inch steel pipe, with threaded caps on the ends. Entering the upper cap at a slight angle was the 3-inch pipe *P*, 4½ feet long which supported the cap *C* of Fig. 8. The 12-inch pipe was sawn across at the dotted line T_o, so that any device could be placed in the interior of this tank, or removed from it, as desired. The upper section of the tank was lifted off as occasion demanded by a block and tackle. The two ends to be joined were first painted with the wax previously described; and after the tank had been assembled, the joint was painted on the outside with the same wax, *W*, and the entire tank thereafter painted with asphalt varnish.

This tank was used under three conditions:

1st. Tank empty, with the elbow *E* to direct the gas into a swirl such that the gas, while in motion, would not tend to return up the pipe *P*. In this case, some rebound was to be expected from this elbow. This expectation was realized in practice.

2d. Tank empty, and below cut off along the dotted line E_o. In this case, more rebound was to be expected than in Case 1, which was borne out in practice.

3d. Elbow *E* cut at E_o, and tank half filled with ½-inch square-mesh wire fencing. Two separate devices constructed of this wire fencing were used one above the other. The gas first passed through an Archimedes spiral, *J*, of 2-foot fencing, comprising eight turns, held apart by iron wires bound into the fencing. This construction allowed most of the gas to penetrate the spiral to a considerable distance before being disturbed, and of course, eliminated regular reflection. The second device, *J'*, placed under the first, consisted of a number of 12-inch circular disks of the same fencing, bound to two quarter-inch iron rods, *Q*, by iron wires. These disks were spaced one inch apart. The three upper disks were single disks, the next lower two were double, with the strands extending in different directions, the next two were triple, and the lowest disk of all, two inches from the bottom of the tank, was composed of six individual disks. This lower device necessarily offered large resistance to the passage of the gas; yet strong rebound from any part of it was prevented by the spiral just described. With this third arrangement, small rebound was to be expected, which also was borne out in practice.

This tank was exhausted by way of a stopcock at its lower end, *S*; and air was also admitted through this same stopcock.

The circular tank, Fig. 13, was 10 feet high and weighed about 200 lbs. It consisted of a straight length of 3-inch pipe, carefully fitted, and welded autogenously, to a four-foot, 3-inch, U-pipe. The straight pipe entered the U-pipe on the inner side of the latter, and at as sharp an angle as possible. Another similar U-pipe was bolted to the first by flanges, with 1/16-inch sheet rubber packing between.

In this tank the gases were shot down the straight pipe, entered the upper U-pipe at a small angle, thus avoiding any considerable rebound, and thence passed around the circular part—not returning up the straight pipe until the velocity had been greatly reduced by friction.

In order to make the time, during which the velocity was being reduced, as long as possible, the pipes were carefully cleaned of scale. Care was taken to cut the hole in the rubber washers, between the flanges, so wide that compression by the flanges would not spread the rubber into the pipe, and thereby obstruct the flow of gas.

Notwithstanding all these precautions, evidence was had that the gases became stopped very rapidly. This was to be expected inasmuch as there is solid matter, namely, the wadding and wire, that is ejected with gas, which accumulates with each successive shot. This solid matter must offer considerable frictional resistance to motion along the U-pipe, and, since the mass of gas is only of the order of a gram, must necessarily act to stop the flow in a very short time.

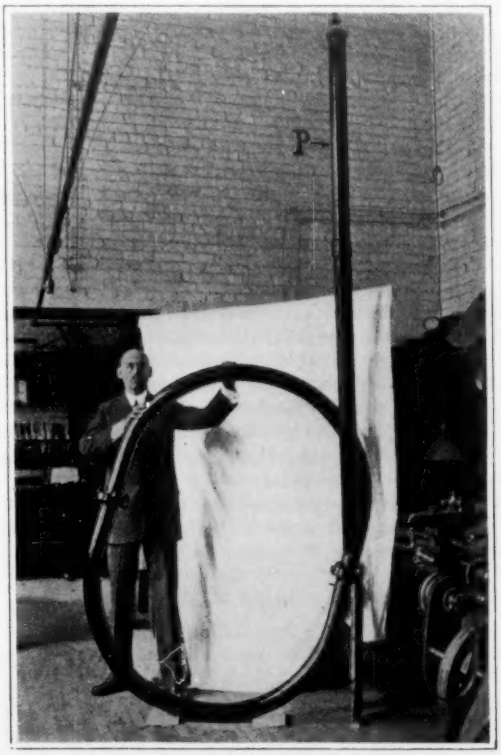


FIG. 13. THE CIRCULAR TANK

This interval of time was great enough, however, so that this second method afforded a satisfactory check upon the first method.

A possible modification of the above two methods would have been to provide some sort of trap-door arrangement

whereby the gases, after having been reduced in speed in a container as just described, would have been prevented from returning upward into the 3-inch pipe *P* by this trap, which would be sprung at the instant of firing. In this way gaseous rebound would be entirely eliminated. It was found, however, that results with the two methods already described could be checked sufficiently to make this modification unnecessary.

The tanks were exhausted by a rotary oil pump, supported by a water jet pump. In this way the pressure in the cylindrical tank could be reduced to 1.5 mm. of mercury in 25 minutes and to the same pressure in the circular tank, in 10 minutes. The pressures employed in the experiments ranged from 7.5 mm. to 0.5 mm.

METHODS OF DETECTING AND MEASURING GASEOUS REBOUND.

With the two tanks used in the experiments, it was obviously impossible to eliminate gaseous rebound entirely, from the fact that, even if the velocity of the gases is reduced to zero, there still remains the effect of introducing suddenly a certain quantity of gas into the tank. It became necessary, then, to devise some means of detecting, and, if possible, of measuring, the extent of the rebound.

Three devices were employed, one for detecting a *force* of rebound, and two for measuring the magnitude of the *impulse per unit area* produced by the rebounding gas. These latter devices, from the fact that quantitative measurements were possible with them, will be called "impulse-meters."

TISSUE PAPER DETECTOR.

The detector for indicating the force of the rebound consisted of a strip of delicate tissue-paper, *I*, Fig. 8 and Fig. 12 (a), 0.02 mm. thick, with its ends glued to an iron wire, *W*, as shown in Fig. 12 (a). This iron wire was fastened to the yoke *Y*, Fig. 10, and held the tissue paper, with its plane horizontal, between the chamber and the wall of the 3-inch pipe, *P*. In many of the experiments, the paper was cut 1/3 the way across in two places before being used, as shown by the dotted lines *h* in Fig. 12 (a). Since the tissue paper has very little mass, the tearing depends simply upon the magnitude of the force that is momentarily applied, and not upon the force times its duration—*i. e.*, the impulse of the force. The tissue paper will tear, then, if the force produced by the first upward rush of gas, past the chamber into the space in the 3-inch pipe above the chamber, exceeds a certain value. This first upward rush of gas will, of course, produce a greater force than any subsequent rush, as the gas is continually losing velocity. Even though the magnitude of the force that will just tear the tissue paper be not known, it may safely be assumed that if the first upward rush does not tear the paper, the force due to rebound that acts upon the gun must be small compared with the impulse produced by the explosion of the powder.

It should be noted that the tissue paper tells nothing as to whether or not there are a number of successive reflections or rebounds gradually decreasing in magnitude; neither does it give information concerning the *downward* pressure the gases exert upon the chamber tending to decrease the displacement, after they have accumulated in the space between the top of the chamber and the cap *C*, Fig. 8.

DIRECT-LIFT IMPULSE-METER.

A section of the direct-lift impulse-meter is shown in Fig. 12 (b). It is also shown in the photograph, Fig. 8, at *A*. A small cylinder *A* of aluminum of 1.46 grams mass, hollowed at one end for lightness, was turned down to slide easily in a glass tube *G*. This tube, *G*, was fastened by de Khotinsky cement to an iron wire *W*, which was in turn fastened to the yoke *Y*, Fig. 10, so that the glass tube, *G*, was held in a vertical position, between the chamber and the wall of the 3-inch pipe—similarly to the tissue paper. Two small wires *C*, *C*, of spring brass were cemented to the top of the aluminum cylinder, the free ends just touching on opposite sides of the glass tube. The inside of the glass tube was smoked with camphor smoke above the point marked *X*, so that a record was made of any upward displacement of the aluminum cylinder. The cylinder was prevented from dropping out of the glass tube by a fine steel wire, *w*, cemented to the tube and extending across the lower end.

There are two advantages of this form of impulse-meter. First, friction acts unavoidably to reduce the displacement. Secondly, any jar to which the apparatus is subjected on firing will cause the aluminum cylinder to jump, and thus give a spurious displacement. This latter fact rendered the meter useless for experiments in which direct lift of the chamber took place, as there was always much jar when the heavy chamber fell back, after being displaced upward.

This impulse-meter, it will be observed, gave a mean measurement of any successive up-and-down rushes of gas.

SPRING IMPULSE-METER.

A section of the spring impulse-meter is shown in Fig. 12 (c). The apparatus consisted of an aluminum disk, *D*, cemented to a lead rod, *L*, of combined mass 5.295 gms. supported by a fine brass spiral spring, *S*. The disk, *D*, was of a size sufficient to slide easily in a glass tube, *G*. The upper end of the spirng protruded through a small hole in the glass tube, and was fastened at this point by de Khotinsky cement, it thus being easy to make the top of the lead rod level with the zero of a paper scale, *K*, pasted to the outside of the glass tube. A piece of white paper placed behind the tube, *G*, made the motion of the lead roll *L* very clearly discernible.

This impulse-meter was placed in a hole in the upper cap of the 12-inch pipe of the cylindrical tank, at *D*, Fig. 11, and the same distance from the wall of the 12-inch pipe as the center of the 3-inch pipe. It projected one inch through the 12-inch cap which was practically the same as the distance the 3-inch pipe projected. The tube, *G*, was kept in position in the cap by being wrapped tightly with insulating tape, the joint being finally painted with the wax already described.

One important advantage of the spring impulse-meter over that employing direct lift is that the former has very little friction, so that the readings are very reliable. Another advantage is that the displacement of the former will include without any uncertainty the effect of any number of rebounds following one another in rapid succession—*i. e.*, the effect of multiple reflections of the gas, if such reflections are present.

In the vacuum experiments, the soft steel chamber was used for Du Pont powder, and the nickel steel chamber for Infallible powder.

The three nozzles were used, called short, medium, and long, and they were respectively 9.64, 15.88, and 22.08 cm. from the throat to the muzzle.

(*Here follows a table of experiments which for lack of space we have omitted.*—EDITOR.

DISCUSSION OF RESULTS.

1. There is a general tendency for the velocities *in vacuo* to be larger than those in air, for the same length of chamber, *l*, and the same mass of powder. For the medium nozzle, with Infallible powder, a comparison of experiments shows that the increase amounts to 22 per cent of the velocity in air.

2. The medium nozzle gives, in general, greater velocities than the short or the long nozzle with the same length of chamber, *l*, and approximately the same charges of powder.

3. The results show no appreciable dependence of the velocities upon the pressure in the tank between 7.5 mm. and 0.5 mm., and it is safe to conclude that the velocities are practically the same from atmospheric pressure down to zero pressure, except as regards the slight increase of velocity with decreasing pressure already mentioned.

4. A comparison of the results when the chamber moved under the influence of the spring with those in which the

chamber was merely lifted, show that the agreement of results obtained by the two methods is good, provided the displacement in the direct lift experiment is small. If, on the the other hand, the displacement in the direct lift experiment is *large*, this method gives considerably less velocities than the spring method. It is evident that *all the velocities obtained by experiments in which the lift exceeded ¼ cm. are from* 300 *to* 600 *ft. sec. too small.* This is a very important conclusion, for it means that the highest velocities *in vacuo*, recorded in the table, are *doubtless considerably less than those which were actually attained.*

5. A comparison of the results obtained by means of the circular tank with those obtained by means of the cylindrical tank shows that the velocities range about 100 ft./sec. higher for the circular tank—a difference that is so small as to be well within the accidental variations of the experiments.

Concerning the behavior of the cylindrical tank under different conditions, a comparison of experiments shows that the velocities are much the same for all cases. Hence it is safe to conclude that the rebound, at least for small charges, is not excessive even if an empty tank is used, providing it is sufficiently large.

6. Concerning the proportion of the measured reaction that is due to gaseous rebound, the tissue paper detector, as has already been explained, does not give any information. All that this detector really shows is that the *force* exerted by the intial upward rush of gas past the chamber is not excessive.

The gaseous rebound could not be measured accurately with the direct-lift impulse-meter.

The spring impulse-meter used in the last five experiments gave reliable results because of the very slight friction during operation. This impulse-meter shows that, if the momentum of the chamber were to be corrected for gaseous rebound, *this correction would be much less than one per cent of the momentum of the chamber.* But as has been stated above, the impulse of the rebound at the chamber must be less than that at the impulse-meter, from the fact that gases may pass readily behind the chamber, and exert a downward pressure, and also because of friction in the 3-inch pipe. The effect of gaseous rebound is therefore negligible, and no account of it has been taken in calculating the velocities and efficiencies.

It now becomes possible to find, from the experimental results, the highest velocity *in vacuo* upon which dependence may be placed. This is evidently the result of Experiment 45 and is 2.34 km./sec. or 7,680 ft./sec. But Experiment 50 would have given without doubt, a velocity even higher, had friction properly been taken into account.

DISCUSSION OF POSSIBLE EXPLANATIONS.

1. The fact that the velocities are higher *in vacuo* than in air seems explicable only by there being conditions of ignition different *in vacuo* from those in air; although this may also have been due to the air in the nozzle interfering with the stream-lines of the gas, thus producing a jet not strictly unidirectional. It should be remarked that the highest velocity *in vacuo* recorded may have been due to unusually good circumstances of ignition; but may also have been due, in part, to being performed in the circular tank.

2. The fact that the medum nozzle gives in general velocities higher than the long nozzle shows that very likely after traveling the distance from the throat equal approximately to the length of the medium nozzle, the gas is moving so rapidly that it fails to expand fast enough to fill the cross-section of the nozzle. The efficiency could doubtless be increased by constructing the nozzle in the form of a straight portion, corresponding to a cone of 8° taper, for the length of the medium nozzle, with the section beyond this point in the form of a curve concave to the axis of the nozzle.

CONCLUSIONS FROM EXPERIMENTS.

1. The experiments in air and *in vacuo* prove what was suggested by the photographs of the flash in air, namely, that the phenomenon is really a jet of gas having an extremely high velocity, and is not merely an effect of reaction against the air.

2. The velocity attainable depends to a certain extent upon the manner of loading, upon the circumstances of ignition, and upon the form of the nozzle. Hence, in practice, care should be taken to design the cartridge and the nozzle for the density of air at which they are to be used, and to test them in an atmosphere of this particular density.

SIGNIFICANCE OF THE ABOVE EXPERIMENTS AS REGARDS CONSTRUCTING A PRACTICAL APPARATUS.

It will be well to dwell at some length upon the signficance of the above experiments. In the first place, the lifting power of both powders is remarkable. Experiment 51 shows, for example, that 42 lbs. can be raised 2 inches by the reaction from less than 0.018 lb. of powder. One interesting result is the very high efficiency of the apparatus considered as a heat engine. It exceeds, by a wide margin, the highest efficiency for a heat engine so far attained—the "net efficiency" or duty of the Diesel (internal combustion) engine being about 40 per cent, and that for the best reciprocating steam engine but 21 per cent.

It is, however, the velocity which is of the most interest. The highest velocity obtained in the present experiments is 13 ft./sec. under 8,000 ft./sec., thus exceeding a mile and a half per second (the "Parabolic velocity" at the surface of the moon), and also exceeding anything hitherto attained except with minute quantities of matter by means of electrical discharges in vacuum tubes. Inasmuch as the higher velocities range between seven and eightfold that of the Coston rocket we should expect a reduction of initial masses to be made possible by employment of the steel chamber, to at least the *seventh root* of the masses necessary for a chamber like the Coston rocket.

The supposition is, of course, that the mass of propellant material can be made so large in comparison with the mass of the steel chamber, that the latter is comparatively negligible. No attempt was made in the present experiments to reduce the chamber to its minimum weight. The minimum weight for the same thickness of wall as in the experiments, was calculated by estimating, first, the volume of a chamber from which all superfluous metal had been removed, and then calculating the mass of this reduced chamber, from the measured density of the steel.

It should be mentioned that, for any particular chamber, it will be necessary to determine the maximum possible powder charge to a nicety, from the fact that, as modern rifle practice has demonstrated, one charge of dense smokeless powder may be perfectly safe for any number of shots, whereas a slightly larger amount, or the same amount slightly more compressed will result in very dangerous pressures.

But the whole question of ratio of mass-of-powder-to-chamber is without doubt relatively unimportant for the following reason: The photograph of the flash, Fig. 5, in which the flash was accidentally reflected in the nozzle of the gun, shows the nozzle appearing stationary in the photograph, thus demonstrating that the duration of the flash is very small; but this, as already explained, is much longer than the time during which the gases are leaving the nozzle. The time of firing is, therefore, extremely short. This is to be expected, inasmuch as the high pressure in the chamber sets in motion only the small mass of gas and wadding, and hence must exist for a much shorter time than the pressure in a rifle or pistol. For this reason the heat such as is developed in the machine-gun, due to the hot gases remaining in the barrel for an appreciable time during each shot, as well as that due to the friction of the bullet, will be absent in the type of rapid-fire mechanism under discussion. Hence a large number of shots, equivalent to a mass of powder greatly exceeding that of the chamber, may be fired without serious heating.

Sources of Power Known and Unkown*

Vast Stores of Atomic Energy

By Sir Oliver Lodge, D.Sc., Sc.D., LL.D., F.R.S.

ALL that the human race can do in the material world is to move matter. To this end our muscles are designed, and only with their aid can we operate. Moreover, it is really through our muscles that we primarily enter into relation with the material world. Our muscular sense has informed us of the existence of an external world; it is that sense which enables us to interpret the indications of other senses, and which clearly discriminates "matter" from what might have been sensory illusion. All our physical activities may be summed up as the movement of matter; indeed, even our bodies are so composed, and are what we move in the first instance. The mind is in a different category, and when we think or will or remember, or suffer or enjoy, we are not necessarily moving matter; though usually some brain process accompanies these mental operations; but when a poet or a musician tries to express or record his thoughts, he has no other means available than to move a pen over paper, or work a violin bow or a keyboard, or of course he may set in action the muscles of his throat, and generate vibration in the air that way.

That the whole function of an engineer is to move matter is fairly obvious. Civil engineers, in a spirit of inverted pride, sometimes denote themselves as "dirt-shifters"; but the construction of a bridge, or of an engine, or of a dynamo, can also be described as the shifting and placing together of material objects. The farmer and gardener again, do nothing else. All real operations, from the production of electrical currents to the growth of seeds, are performed by Nature. Locomotion, in one form or another, is the business of man.

Every form of physical activity requires power; hence power or energy is the most pressing material need of man. Food and fuel obviously belong to the same class; for whether the power exerted be directly muscular or indirectly mechanical, makes no difference in principle. Yet there is a difference. Food is mainly used by an animal for developing energy before it has assumed the form of heat. Fuel, unfortunately, at the present time, has to produce heat first, so that the heat can be employed in some form of heat engine. We are thus up against the conception of temperature, and the inexorable law of efficiency, $\frac{T-T^1}{T}$. Heat can only be used when it falls in temperature from a hotter body to a cooler, and it is liable readily to fall in temperature without being utilized. When that happens there is loss of efficiency, and consequent waste of available power. A flagrant instance of fall of temperature with nothing to show for it, is the drop of temperature between furnace and boiler. All the heat may be transmitted through the walls of a perfect boiler, but it has become heat at a much lower level. The subsequent drop of temperature from boiler to condenser is utilized to the utmost by a multitude of ingenious devices from Newcomen and Watt down to Sir Charles Parsons, whose engines I suppose utilize this fall of temperature in the most direct possible manner. But if the temperature of combustion could be made use of, as in a frictionless flame turbine, more of the fuel energy could be utilized. Internal-combustion engines attempt this, no doubt successfully up to a point; but so long as they require cooling jackets, whereby heat falls in temperature without doing work, so long they are imperfect. Utilization of undesired local heat to generate high pressure steam, would seem likely to be a step in the right direction, and an engine with flame on one side of the piston and steam on the other has become known.

But animals do not turn their food energy into heat at all—save what is needed for warmth. Nor does a voltaic battery turn its chemical energy into heat. Any heat produced is waste: the chemical energy ought to go direct into an electric current; and an electric motor is capable of utilizing current energy very efficiently. Unfortunately, the chemicals are expensive, and it pays better to conduct electrochemical operations by aid of a dynamo and expenditure of mechanical energy, than to obtain mechanical energy from electrochemical operations.

It is important to realize that the law of efficiency $\frac{T-T^1}{T}$ is only applicable when the terms "heat" and "temperature" are applicable. The second law of thermodynamics refers to heat only, and not to any other form of energy. It does not apply to moving objects directly harnessed—like a fly-wheel; nor would it apply to molecules if their motion could be directly utilized. Organized and systematic motion is not "heat." In so far as the sun is a hot body, the formula is applicable, but it is a body at so excessive a temperature that the efficiency is nearly perfect. The fall of temperature from earth to absolute zero is 300°, but the fall from sun to earth is about 6,000°, hence the efficiency is $\frac{5900}{6000}$, or $\frac{59}{61}$, or very nearly unity. The leaves of trees, and vegetables generally, are able therefore to absorb and utilize solar energy in the refined chemical operations needed for the production of wood and coal, as well as of food, and they seem able to do this without much regard to any hampering law of efficiency.

This is undoubtedly the best way of utilizing present solar energy; and the moral is—promote agriculture of every kind, and in the widest sense. The solar rays which fall on the sea are not wasted; they are needed for wind and rain, and they give us all our water-power, but solar rays fallen on barren soil or hopeless jungle are a reflection on humanity: that kind of waste ought not to occur. The progress of bacteriological science might make every soil fertile; even rocks can be dynamited into something; and jungles and swamps should be cleared. We are not living in the carboniferous epoch, and we cannot wait millions of years for the contemporary production of coal.

But it is not food and fuel alone that we get from the present-day sunshine: We get wind and water-power, too; and it is economical to use them where we can. The beauty of a waterfall is enticing, but looked at with an engineering eye many waterfalls suggest a sad waste of power. And even when there is not a waterfall, so called, all water in descending from high-level lakes to the sea must be able to give out power which might be used wherever it is convenient to harness it.

In other ways the present sunshine may be utilized. I cannot regard with hope the idea of merely converting it into low-temperature boiler-heat. The barrenness of the Sahara would be the only excuse for the extensive use of burning-glasses or mirrors, and it is, perhaps, the only kind of place where such an enterprise could rationally be contemplated. But then there are very few parts of the Sahara where power is particularly wanted. Economy of transmission has a limit.

[A digression on the energy of the past sun may be permitted. All that the earth has caught, for all the millions of years that it has existed, is the merest fraction of what the sun has radiated in the same time. The earth to the sun is like a printer's full stop at a distance of ten feet from a halfpenny. Some of the radiation from a globe one inch in diameter falls on the spot $\frac{1}{100}$ in. in diameter ten feet away, but that little speck only catches the hundred and fifty millionth part of the whole. What has become of the rest of the solar energy? It must still be careering through space.

*Lecture delivered before the Royal Society of Arts, Dec. 10, 1919.

The ether is perfectly transparent, and only when it encounters matter will the radiation be mopped up and turned into heat. Not our sun only, but all the millions of other suns, have likewise been always pouring out radiation into space. Is there any hope of catching and utilizing it? I trow not. In spite of all this constant flood of energy, space is cold; very near absolute zero. The reservoir is so enormous that all these taps, running for ages, have made no impression on it, have not raised the level a perceptible amount.]

The only portion of the past solar energy available to us is that which was caught and stored by vegetation. This it is which has produced combustible matter; this it is, probably, which has also liberated free oxygen into the air.

The amount of atmospheric oxygen, and the amount of combustible matter in the earth's crust, were believed by Lord Kelvin to correspond; one was the chemical equivalent of the other; they had been separated by solar radiation. If so, the amount of combustible matter, of every vegetable kind, in the earth's crust can be estimated; for it is easy to estimate the amount of oxygen in the air.

The amount of combustible matter is limited, but the oxygen of the atmosphere is also limited. We have not exhausted the total fuel supply as yet, and it is to be hoped that we never shall attempt it. It would be poor progress if the human race, in pursuit of mechanical activity, were to burn up the air it breathes. There is plenty left at present, but no thanks to human beings or animals that it is so. All our factories burn it up. Only vegetation restores and renews it. We used to burn up the air of our rooms in order to light them; we do better than that now. The utilization of chemical or molecular energy seems necessarily limited. A great consumption of material yields comparatively little power. More plentiful and cleaner power is wanted. Some other source of energy ought to be discovered before the human race is a century older.

Are there any sources of energy not derived from the sun? Yes, two. The internal heat of the earth and the tides. Internal heat of some kind, whether due to radioactivity or otherwise, makes itself manifest in the neighborhood of hot springs and volcanoes. The eminent Italian engineer Signor Luiggi Luigi has shown us how to bore into the bowels of Vesuvius and extract from it some of its energy in a practical manner. A remarkably interesting achievement!

The utilization of the tides is continually being pressed by amateurs, but engineers rather take their stand with Lord Kelvin in recognizing the extreme slowness of tidal operation. They realize the vast reservoir that would have to be filled and emptied every twelve hours, and how likely it is that the reclaimed land of the reservoirs would be of more value than the power; at least in any locality where the power was really wanted, without prohibitive distance of transmission.

The power of waves is different. That does come from the sun, and it is not leisurely like the tides. Those who have watched Atlantic rollers booming into creeks on the west coast of Ireland have felt that here surely was available power. We may imagine a dreadnought (now let us hope of no further use) attached by a long girder to rack-work machinery, and being hoisted up and down by the waves. The weight that could thus be hoisted might be far greater than a dreadnought—the whole German fleet for instance might be attached to the lever; it would give a good many foot-tons per minute; but whether any machinery would stand the strain I do not know. The idea is probably absurd, but it seems to me less problematical than the tides. Besides, in large harbors the tides are wanted for scouring purposes, and for clearing away a bar.

Is there any concealed store of energy recently discovered and not yet utilized? There is indeed. There are two,—one certain, the other rather hypothetical: the energy of the Atom, and the energy of the Ether. I propose to say nothing about etheric energy. If it exists, as I think it does, it is enormous, exceeding the bounds of imagination; but at present it is utterly beyond our reach. Atomic energy is rather inaccessible too, but not hopelessly so. It is far less in amount than etherial energy, but it is immense compared with any form of chemical or molecular energy, such as that derived from combustion or explosives.

By atomic energy I mean the constitutional energy of an atom—the energy which makes it what it is. If this energy is given up in any considerable degree, the substance ceases to be what it was, and becomes a substance lower down in the scale. Utilization of atomic energy would involve the stepping down, the degradation, of matter. The term is purely technical—it has been already applied to energy without moral stigma. All it means is that heavy atoms may become lighter atoms, and in so doing must give off a definite proportion of their great store of energy.

This spontaneously happens in the phenomenon known as radio-activity. If it had not spontaneously happened, we should have known nothing about the energy concealed in an atom. The explosive or radio-active atom has given the secret away. All atoms possess energy, but some cannot hold it all. These are the radio-active elements, and they periodically fire off projectiles with more than volcanic violence. A radium atom firing off a particle, which turns out to be a postively charged atom of helium, is like a two-ton gun firing a hundred-pound shot. That is about the actual proportion between the projectile and the rest of the atom; which naturally recoils each time it fires. The recoil has been observed. Before it has exhausted its ammunition it fires off five such projectiles, and then settles down into a quieter existence as lead—or, if not exactly lead, something chemically indistinguishable from lead. A uranium atom had already fired off four projectiles in order to become radium. Radium is a temporary half-way house between uranium and lead: it is active, but not so fiercely active as some of the intermediate substances, which last so short a time that they barely have names. They destroy themselves by their own activity, and consequently are very scarce—like a population with a high death-rate. Radium is of moderate activity; its lifetime is of the order of a thousand years, whereas the lifetime of some of the intermediate substances may be measured in weeks or even minutes. Yet they are real elements, with a place in the series, and they have definite spectra and chemical properties.

Do not suppose that the well-known radium is an exceptional substance. It would seem that all substances of very high atomic weight are liable to behave in this way—it is only a question of degree. And it is not by any means their whole energy that they thus exhibit, it is the energy they expend and get rid of—their waste energy—which we perceive. And when we speak of their explosion, it is to be noted that the explosion is not a shattering or bursting of the gun, it is merely the firing of a shot; except that in the atomic case the shot was part of the gun. The energy retained is far more than the energy expended. And when its active transformations have ceased and left it in a stable state, like lead or gold or silver or copper or iron, or any common element, we are not to suppose that because it is quiescent therefore it has no store of internal energy. Appearances are deceptive. Anyone looking at cordite might think it harmless enough; and so it is till a suitable stimulus is applied. It does not go off spontaneously, or at least it is not wanted to. Gunpowder and any other explosive exhibits no trace of its secret to mere inspection; nor do the atoms of ordinary matter show that they are fearfully energetic; but the energy is there.

We may now go on to ask: What corresponds to the gunpowder, when I speak of a gun firing a shot? What propels the projectile? It is a very proper question, but at present it can only be partially answered.

There are two kinds of projectiles fired off by a substance—

the heavy shot or α ray, which is known to be a helium atom, and the lighter shot or β ray, which is the fundamental unit of electricity, the negatively charged unit particle—an electron. Several electrons may be expelled, and they will not make much difference to the weight of substance left behind, but they will have left it positively charged; and in that case it is liable to fling away one of its massive positively charged particles, too. One event follows the other, and whether the electron always escapes first is uncertain. Whichever event precedes, in different cases, the other is likely to follow.

Many circumstances can stimulate the escape of an electron; not, in deed, of the deeper-seated constitutional electrons, but of the outlying superficial charges which are responsible for chemical affinity. Mere friction removes some of them, and leaves the substance positively charged. The removed electrons will have gone to the rubbing substance, and will have charged it negatively. Splashing of water, chemical action in innumerable forms, effects the transfer of electrons, and consequent charging of bodies. Ultra-violet light falling upon clear metal, and indeed upon a large variety of substances, causes electrons to be expelled, until the surface is positively charged enough to hold them back. The discharge will go on continuously if more are supplied from a battery. The jostling of the molecules by heat will often cause electrons to escape, but not usually until a temperature of red or white heat is reached. Singularly enough, a comparatively low temperature will emit a few positive particles for a time; but this emanation soon ceases, the material gets tired as it were, and has to be re-born or renewed somehow, if the process is to be continued. Not so with the negative emission from hot bodies. This will go on as long as fresh particles are supplied.

In many ways, therefore, we can stimulate the escape of stray electrons, and it appears that by the aid of X-rays, or of projectiles from other atoms, we are beginning to learn how to disturb effectually, and even to eject, the deep-seated constitutional variety; though usually others immediately take the place of the ejected one, with consequent radiation of definite type. If a pair of β particles were permanently extruded, an α ray would probably follow, in order to restore the neutrality of the atom; and the atom would have gone a step down in the scale. This happens spontaneously, but the result of experience is that we cannot bring about the catastrophe by ordinary means. We cannot alter the spontaneous rate, by anything we as yet know how to do. Heating and cooling alterations of molecular movement—seem impotent to get down to the inner mechanism. Still, we are certain that inner mechanism is a most energetic system; and just as the internal charges are equally positive and negative, so I believe atomic energy is both static and kinetic—though perhaps not equally so.

The modern view of an atom is a central positive nucleus like a sun, and a revolving system of negative electrons like planets. The electric planetoids, so near this "sun," and subject to its powerful electrical attraction, must be revolving with prodigious speed, and with a frequency of orbital revolution exceeding in most instances even the frequency of light—a frequency only attained in general by the ultra rapid X-rays. Accordingly, these little bodies have plenty of kinetic energy, and when they escape as β rays, they do so with something like the velocity of light.

The *frequencies* possible in a hydrogen atom turn out, in Bohr's theory, to be of the order 10^{15}, being either 10^{15} itself or else $\frac{1}{8}$ of 10^{15}, or 1/27 of 10^{15}, the denominators being the natural cubes. For heavier kinds of atoms, this frequency must be multiplied by the square of the number allotted to the element in Mendelejeff's series.

The *diameters* of the orbits will be of the order 10^{-8} cm. divided by the atomic number and multiplied by the successive square numbers, 1, 4, 9, etc.

The *velocities* will be of the order 10^{9} cm. per second multiplied by the atomic number and divided by the natural numbers, 1, 2, 3, etc.

So for the heavy atoms, whose atomic number is approaching a century, the inner electron speeds are getting near to the velocity of light; hence probably their instability.

The positively charged nucleus is in different case. Its energy is more likely to be static, *i. e.* potential, like things held or caught together, as a detent may hold a strong spring. Let them be liberated, and they fly with great violence, presumably under electrical repulsion; the potential gradient near the nucleus is enormous, and the speed therefore very great, so that each atom where it strikes a zinc sulphide target makes a luminous splash. Taking the size of the nucleus as comparable to 10^{-12} cm., the acceleration of an α particle is Ne^2/Kmr^2, m being the mass of a helium atom; and this equals $3 \times 10^{25}N$ centimeters per second, at the start, and must be reduced to near zero at the confines of the atom. (N is the atomic number.)

The projection of an α particle is therefore literally an explosion, and the force can very quickly get up an enormous speed. (The acceleration of a bullet in a rifle is comparative to 10^{7} or 10^{8} of the same units, at most.) The speed with which an α particle is ejected is about one-fifteenth that of light—sufficient to carry it to New York, if there were no obstruction, in a quarter of a second. Its energy is therefore, weight for weight, a million times that of a bullet. Only because an atom is so small does it fail to do any damage.

But the number of projectiles from a milligramme of radium is about thirty million a second; hence, in the aggregate, they generate a very perceptible amount of heat. We may not know the exact cause of their retention, or of their propulsion, but no one can deny that the energy is there. The main difficulty is to understand how they are retained and packed together into the exceedingly minute nucleus. The natural suggestion is that the cement consists of interleaved or interlocked negative electrons; and when these are dislodged by some perturbation from the orbital part of the atom, or by the impact of a projectile, the liberated positive particles are driven asunder.

As to the atoms' orbital electron energy, that is probably kinetic, they probably escape with the velocity with which they were revolving in their orbits before perturbation. This is rendered plausible by the fact that their emission depends on synchronism between the periods of the particles and the X-ray disturbance which ejects them. Their energy of ejection is found to depend on the frequency of the radiation which stimulates it; a fact which at once suggests a storing of received synchronous vibrations, till a quantum of energy sufficient for ejection has been accumulated. Moreover, spectrum analysis of the derived or secondary X-rays, emitted by a substance exposed to radio-active bombardment, is also a test of the frequency of orbital revolution.

Particles can be ejected from one of several orbits—called respectively K or L or M, the K orbit being the nearest to the nucleus and therefore of highest frequency. Electrons are ejected at speeds still greater than α particles, and occasionally approach to within a few per cent of the speed of light.

If we calculate the amount of energy thus quietly existing in the atoms of any visible piece of matter, we shall find it enormous. If each atom is the seat of these high velocities, and equivalent high explosive forces, the aggregate of energy in a few trillion atoms is very great; and it takes fully a trillion atoms to make a perceptible speck of matter.

To illustrate the energy possible in any reasonably small quantity of substance, it is sufficient to reckon the energy in a couple of grammes, or say thirty grains, of matter moving at one-tenth the speed of light. It need not be moving in the sense of locomotion; internal motion of its parts does just as well; and static energy can be equally well included, since its liberation will produce these high velocities. The energy is 10^{19} cgs. units or ergs. Now a foot-ton is 3×10^{10} ergs.

Hence the energy of a few grammes of matter is three hundred million foot-tons, enough to raise a hundred thousand tons 3,000 feet. If all its parts were moving with the speed of light, the energy would be a hundred times greater, but it is doubtful whether bodies can move at quite the speed of light. For, just as a bullet cannot move quicker than a thermally modified velocity of sound, so a body is unlikely to move through the ether quicker than the ether disturbance can get out of the way.

No doubt a large store of energy is there; the practical question is, can we get at it and utilize it? We may even ask: Is any of it being utilized already? I do not think the answer is wholly in the negative; for that the activity of radium, theorium, and other radio-active substances, is employed therapeutically is well known. That was the beginning of practical application of the energy given off.

Atomic energy may unconsciously be being utilized in other ways, too. I have lately put forward an incipient radio-active theory of vision: I surmise that in the retina there must be a substance which can be stimulated into activity by the impact of ether waves of luminous frequency, that the substance then ejects a few of its outlying electrons, and that these stimulate the nerve-endings in their immediate neighborhood. The way in which air vibrations stimulate the auditory nerve has been fairly made out; it is a question of mechanism; but the way an etherial vibration stimulates the optic nerve has not been made out: it is not a mechanical, but an electrical question. Radiation of high frequency is known to be received and stored until it is able to eject a negative particle with whose orbital frequency it happens to agree. And certainly such a particle when ejected could be depended on to stimulate a suitable nerve ending.

It is on those lines that I would explain the extraordinary sensitiveness of the eye. For the accumulation of a few million impulses would take no appreciable time, and it is difficult to suppose that in any other way than by synchronisation with some equally rapid intrinsic motion, could matter be perturbed by the extraordinarily rapid vibrations of ether—hundreds of millions of millions per second. Nothing larger than the ultimate elements of the atom could be expected to follow such rapidity. Molecules of matter would be almost too massive and gross to be readily moved as a whole; and, besides, their movement as a whole would only result in heat.

The same sort of idea could apply to the stimulus of a sensitive photographic plate; only here the chemical atoms are attuned, as a rule, to still higher rates of vibration, and are susceptible beyond the ultra violet, into the region of X and λ rays.

The facts of color vision suggest that the visual substance (visual purple, or whatever it is) is specially sensitive to three particular frequencies, one in the red, one in the green, and one in the violet; but there must be plentiful overlapping, so that intermediate wave lengths may produce their full effect.

The whole idea at present is in the nascent stage: only it is instructive to think that possibly atomic energy may have been utilized in the eyes of animals all the time. It is conceivable that it may have been utilized for the light emission of glow-worms, though that is generally and perhaps rightly considered to be due to molecular or chemical energy. Atomic energy is not chemical at all, but physical—at least, when the constitutional and not the outlying electrons are in question. It is possible that the absorption of solar energy by chlorophyll in plants may also in some way utilize atomic energy, stimulated into catastrophic activity by light waves. These things are only possibilities, which observers and experimenters may do well to follow up, and, if need be, negative.

But of late an application of atomic properties *in vacuo* has undoubtedly been made. Ordinary electric valves depend upon the different behavior of positive and negative particles; and an electric bulb containing a positive electrode and a hot wire cathode was employed, some years ago, as a receiver for wireless telegraphy, by Professor J. A. Fleming. When the hot wire or filament is negatively charged, a stream of electrons reach the anode. When it is positively charged, the emission is checked. So if an alternating current is received, the emission of electrons is alternatively helped and hindered, and thus the current is rectified and made capable of being received by any ordinary instrument. The cutting up into signals has to be otherwise managed, for the alternations are too quick to be acoustically perceived.

Then Lee de Forrest introduced an improvement, and made it not only a wireless receiver but a relay or amplifier. Between negative filament and positive anode, in an exceptionally high vacuum, he placed a perforated grid or coiled wire, with interstices that would let the electrons through; and instead of applying the received alternating pulses to the anode, he applied them to the grid, placed above or facing the red-hot cathode, with the anode above or behind the grid. The effect on the escaping charged particles was the same,—the stream of current-carrying particles was helped or hindered, encouraged or stopped, as before; but now a strong battery could be applied between anode and cathode, and some mechanical receiving instrument, telephone or what not, could be placed in the auxiliary or relay circuit. Weak impulses applied to the grid, according to their positive or negative sign, will now serve to control the stronger current in the auxiliary circuit; and so a received message that in itself would be hardly audible can be magnified a hundred-fold.

Electrons emitted by a hot wire are not flung off with any prodigious speed; they seem rather to evaporate off at a red or white heat, and their subsequent course is controlled by the gradient of electrical potential in which they find themselves. The force acting on them is $F=e dV/dx$, and the total work done is $F dx=e dV$; that is to say, the energy generated depends simply on the total drop of voltage through which they pass. Their speed is given by

$$\tfrac{1}{2}mv^2=e\ (V-V^1),$$

and it is usually considered sufficient to specify the voltage through which they drop, as adequately representing their externally generated speed.

They come off with *some* velocity, however; call it u; but a small opposition voltage will suffice to quench this, as gravity quenches the speed of a cricket ball thrown vertically up, and sends it down again. So it is with the electrons from a hot wire. Any potential difference greater than $mu^2/2e$ will return it whence it came. One volt rise in potential would be able to quench a speed of 450 km. per second.

That, then, is what happens between grid and hot wire. If the grid potential is negative, and greater numerically than the minimum value, the stream of electrons from the hot wire is stopped and sent back; if the grid is positive, the speed upward of the lectrons is encouraged. They shoot through the pores of the grid, they reach the anode above it, they establish connection and convey the current. The auxiliary circuit, between anode and hot wire, is completed by them, and the signal is given. But this only happens when the grid allows of their passage. If the potential of the grid is adverse they never pass through it at all, but just return depressed to the hot wire. Electric evaporation is checked, just as the evaporation of water is checked in a closed space, not because no particles spring out, but because an equal number are returned. A positive grid promotes evaporation, a negative grid checks it, an alternating grid causes an alternating stream to pass through it; and the electric stream can follow every minutest fluctuation; for electron inertia is as nothing, and they respond instantly to the slightest force.

To get quickness of response the projectiles must not be allowed to bombard other molecules, so as to ionize them and render the whole atmosphere conducting. For this ionisation would not subside instantaneously, and therefore the current would not be completely under control. To avoid ionisation by impact, the reservoir must be very highly exhausted; the cur-

rent ought to depend on the projectiles themselves, not on their secondary and adventitious effects.

It is to be noticed that the kind of electric emission from a hot wire differs greatly from that stimulated by ultra-violet light or X-rays. These vibratory agents dig right down into the constitution of the atom, and eject electrons whose orbital frequency agrees with their own. The "harder" the ray, that is, the higher the frequency of the impinging radiation, the higher the velocity of the ejected electron—evidently because one of the innermost orbits is then perturbed. For in inner orbits the speed must be high, in accordance with Kepler's third law. The orbital speed varies inversely with the square root of the radius of the orbit. And the more massive the nucleus the greater the speed necessary to balance the centripetal force.

But the jostling of atoms by heat produces no such deep-seated effects. The effect of heat in a metal is as if a kind of atmosphere or crowd of stray electrons evaporated and escaped. It is unlikely that the electrons in a metal are really loose, but some of them are so slightly attached as to be practically loose—readily passed from atom to atom in the process of conduction, and readily expelled under the irregular impulses of heat.

Whether heat is the best way of promoting this electronic emission may be doubted. It seems an extravagant method, analogous to employing an electro-magnet where a permanent magnet would do, or to supporting a roof by a jet of water. But the other kind of stimuli, such as those promoted by radioactivity or ultra-violet light, do not seem to generate the right kind of docile emission. The very high-speed electrons would require too much potential to hold them down. The speed of electrons ejected by X or λ rays is definite, and depends on the frequency of the rays; but the speed of emission of electrons from a hot body is indefinite and irregular, being distributed in accordance with Maxwell's law for a monatomic gas. Moreover, the escape through the skin of a metal is equivalent to an escape against a "contact" difference of potential; and thus, in some cases, the electrons may be said to ooze rather than to fly out, and to owe their subsequent speed entirely to the external potential gradient in which they find themselves.

That state of things would be quite convenient for wireless telegraphy, since they would then be still more readily under control. The skin retardation exerted by tungsten has been measured as 4.6 volts, unless I am mistaken.

To return to practical applications of these atomic properties—for it is atomic properties rather than atomic energy that is at present being utilized. Not only is it possible to employ a relay in the way described, for the emission and receipt of wireless waves, but one relay can be used to stimulate another; and this can be done several times in succession, and immense magnification attained; for the electric stream is so rapidly responsive and docile that it can follow fluctuations that no mechanical relay could possibly follow. The rapidity of signalling thus rendered possible in the Morse Code is surprising. Of course an automatic sender, and some form of chemical or quick-responding receiver, must be used; and then the message can be as rapid as one can speak. The words are spelt out, without abbreviation, in dots and dashes; and yet the words come on to the tape at three hundred a minute, five a second or thereabouts.

It is also becoming well-known that Morse signals need not be used, but that ordinary speech itself can be thus wirelessly but electrically transmitted, with quite good clearness of articulation. Every auditory frequency is slow compared with what the atomic projectiles can follow, hence every variety of speech-sounds, vowels and consonants, can be readily picked up and transmitted into electric fluctuations. This is done at the sending end, and the aerial accordingly emits waves, which, though they have their own electric rate of vibration, succeed one another in batches corresponding to the acoustic frequencies. At the receiving end the succession of waves are picked up by the aerial there, and once more converted back into telephonic speech through the medium of one or more valve relays and appropriate devices.

There are many details, and great ingenuity has been expended in bringing this method of wireless telephony to the perfection which it has thus far attained. The whole thing is most hopeful, and splendid work is being done at wireless research stations. (I have recently seen the Government one at Woolwich, under Colonel Cusins and a devoted staff of workers, and have gone over it with great admiration.)

The interest to us, here and now, is that it is by the harnessing and practical utilization of purely atomic properties, that all this great advance in practical electrical engineering has been accomplished. The conclusion is inevitable that much more remains to be done.

A NEW PROCESS FOR PLATING ARTIFICIAL STONE WITH METAL.

THE varieties and applications of artificial stone have become increasingly manifold in the present century. In 1901, an Austrian inventor, Lundwig Hatschek, took out a patent for a new kind of artificial stone, having as its chief elements asbestos and cement. Tiles of this substance called Eternit and Zenit have been extensively used for building purposes, especially for roofing. However, such tiles are not absolutely impervious to water and to frost. Many attempts, therefore, have been made to improve the material by painting or covering with metal. For example, in one process the tiles were painted with copper and aluminum bronze and then polished, but this application was found to be not very durable. Another attempt was made to cover the stone with a metal coating by means of the Schoop spraying porcess, but since no intimate connection is thus formed between the metal crust and the mass of the artificial stone, the metal peels off in the course of time.

The problem has now been successfully solved, according to the *Elektrochemische Zeitschrift* (Berlin) by an engineer named Henry Welte, after several years of study and experiments. His process, which is patented (DRP. 288,435) furnishes asbestos-cement roofing tiles with a metal overlay which renders them absolutely watertight and resistant to frost. Furthermore, the metal covering clings solidly to the plates of stone. These virtues have been certified to by the Experimental Station of the Technological Trade Museum in Vienna, and the Chemical Laboratory of the Clay Industry in Berlin.

The process of manufacture is exceedingly simple and can be incorporated without trouble in the scheme of any artificial stone works. Before the shaped articles are placed under the hydraulic press the entire surface is covered with powdered metal, which is sifted on so as to form a thin coating. The single particles of the metal powder are given either a spherical or an irregular form, as the case may be. The object is then placed under the press and the pressure causes the upper surface of the particles of metal to be flattened and to unite with each other, forming a uniform layer. This coating is compactly united with the mass of stone by means of the pressure, the cement being forced into the interstices of the particles of metal beneath but without being extruded through the upper surface.

All sorts of objects, tiles, building stones, pipes, etc., can thus be covered with any desired metal. Another advantage which is of great importance is that plates thus covered can be welded together, thus greatly simplifying the making of a water tight and frost tight roof, the upper surface of the stone being covered with lead or copper, or with a lead coating which has been copper plated by the galvanic method. The process also lends itself to decorative purposes, since it can be applied to objects such as bath tubs, bath rooms, washstands, ice boxes, electric fixtures, etc., decorated in relief. This new invention will also be of great value in the construction of chemical appliances because of the resistance to acids attained by the use of the proper metal overlay.

The Apparent Form of the Sky*

A Penultimate Word on This Much Discussed Subject

By Camille Flammarion

The following article is a report of a lecture by M. Flammarion. While the distinguished astronomer here sets forth his views in answer to those expressed in a previous lecture by Dr. Dubief, his address is in no way dependent upon the former for comprehension, both text and illustrations being self-explanatory.—EDITOR.

IF I give to this informal address the title of a *penultimate word* on the apparent form of the heavens, it is because I feel that the ultimate word will never be spoken, and that at any rate I myself should never venture to utter it. The learned and picturesque lecture with which Dr. Dubief has charmed us, has shown, by the new light which he has shed on this ancient question, how complex the subject is and to what varied discussions it can give rise.

It is indeed an ancient question. Yesterday I ran over the titles of 250 memoirs specially devoted to this subject in the course of more than a thousand years. As a curiosity I will set before you one of the oldest dissertations, that of the Arab Alhazen, a tenth century astronomer, whose treatise on optics, translated into Latin in 1270, was published in 1572 under the somewhat heavy form here exhibited. It is a bibliographical curiosity. We might read, had we time, among these demonstrations of refraction, chapters 51 to 55, upon the aggrandizement in size of stars upon the horizon. But I spare you; chapter 55 contains no less than 146 lines of this gigantic format in a single paragraph and in not very classic Latin. You see, Gentlemen, that our ancestors were as laborious as we. Alhazen's opinion was that the vapors of the air were the principal cause of the enlargement of stars upon the horizon. This is still the opinion today of my illustrious friend Camille Saint-Saëns, with regard to which I have been doing battle with him since the days of Samson and Delilah. I have neither the strength of Samson to pull down the walls of a Cyclopean temple, nor the charm of Delilah to dazzle the eye, but I venture to believe that the mere naked truth will suffice to assure the victory.

After Alhazen, as a serious authority, we may cite Kepler. I owe it to the erudition of our colleague, M. Gaston Havet, that my attention has been called to his *Epitome*, which contains the following lines on p. 82 of the edition of 1618:

"Jam vero cum constellationes versantur in coeli medio, corpus aeris nec profundum est, respectu aspectabilis latitudinis terrarum, nec profundum esset, conspici potest ijitur ex absentia corporum interjectorum: ratiocinatur sensus communis per errorem,sidera cum sunt in coeli medio, nobis esse propinquiora, quam cum oriuntur et occident: tunc enim censentur remotiora, quia valles et montes inter nos et orientia sidera longissimo tractu interjecti, patent oculis. Sequitur ijitur error alter, ut sol, qui manet ejusdem magnitudinis, aestimetur culminare parvus admodum, oriri vero ingeus, ut gigas.

"Eorum enim quae videntur eodem angulo visionis, illa sunt majora, quae remotiora, ut docemur in opticis."

This is the explanation which has always seemed sufficient to me: that of the aspect of sky, which seems nearer to us above our heads than at the horizon, as was later set forth by Malebranche and Robert Smyth. At our session of March 5, 1913, devoted partially to this subject, I said, repeating what I had already published in 1872 in the first edition of my work, ***L'Atmospheres*** "The enlargement of the moon, the sun, and and the constellations at the horizon can be completely explained by the fact that they appear more distant than the objects interposed, and we thus judge them to be larger because we instinctively compare them with houses, trees, hills, etc., while when isolated in the heights of the empty sky we judge them to be much nearer. The apparently lowered vault of the sky and this removal in distance are due to the same optical effect, the same illusion."

And this is the *résumé* of what we said here at our 1911 meetings:

"It is incontestable that the sun and the full moon appear much larger when they are rising or setting than when at a certain height in the heavens, perhaps two or three times as great in diameter, in a really colossal proportion. The same thing is true of the constellations. Orion is gigantic, and that indeed is the origin of his appellation. But this enlargement is only apparent, due principally to the form of the flattened vault of the sky, which enlarges the projection of the angles from the zenith to the horizon.

"Look at the sky in cloudy weather and you will perceive that the clouds situated above our heads are much nearer us than those at the horizon. The cumulus clouds float at 1000, 1200, 1500 meters above our heads, while the horizon is 5, 6, 10, 15, or 20 kilometers distant or more, according to the place of observation. From my observatory at Juvisy, for example, we see the Eiffel Tower 20 kilometers distant. From the ramparts of the city of Langres Mont Blanc can be seen, at a distance of 245 kilometers. The apparent sky is therefore an almost flat roof not bending downward except at a great distance. The far clouds seem poised upon the horizon. Thence results this vault in the form of a furnace, this flattened pressed vault to which we are accustomed, and which does not differ very much even in the clearest sky, because of the accustomedness of the eye and because of the degradation of the color from blue to gray."

The sides of the angles drawn from the center of the celestial hemisphere to its circumference diverge from the zenith to the horizon as they cut this flattened vault, as can easily be seen in Fig. 1, which was published in the first edition (1872) of my work, *L'Atmosphere*.

This figure which resembles that of Malebranche, so brilliantly commented on the other day by Dr. Dubief, was drawn by Robert Smith in his *Course on Optics* (London, 1738), translated into French by Pezenas in 1767, and published by Voltaire in his *Dictionnaire philosophique* under the work "Sky."

Smith concluded from his comparisons that the sky appears three or four times as far from us at the horizon as at the zenith in the proportion of the figure, and that apparent diameters of the moon and sun vary in the following ratios with their height:

Heights of Sun and of Moon	Apparent Diameters
0°	100
15	68
30	50
45	40
60	34
75	31
90	30

The effect is the same for the apparent angular distances of the stars and for the size of the constellations.

It has always seemed to me that we could adopt this explanation.

But are there additional causes? In particular, does the atmosphere produce the effect of a magnifying glass, as maintained by M. Saint-Saëns? It was my desire once more to test

*Translated for the SCIENTIFIC AMERICAN MONTHLY from *L'Astronomie*.

the ideas of an observer meriting such a high degree of consideration. A perpetual demonstration o fthis absence of enlargement had already been furnished by the fact that the measurement of the lunar circles or of the sun spots is not affected by the height of the star above the horizon, except for the well known correction for refraction, which does not change the horizontal diameters, and actually *diminishes* the vertical diameter; but another demonstration, even easier and simpler can be given by photography.

To judge directly whether the sun and the moon are larger when near the horizon, by reason of an optical phenomenon due to the atmosphere acting like a magnifying glass isn't the simplest plan to photograph them? We have done this at the

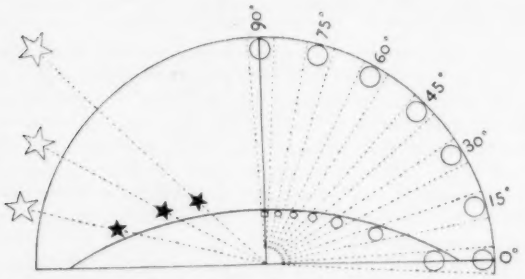


FIG. 1. EXPLAINING THE APPARENT ENLARGEMENT OF THE STARS NEAR THE HORIZON BY THE FLATTENED SHAPE OF THE CELESTIAL VAULT

Juvisy Observatory. Thanks to the well known skill of M. Quénisset many of these photographs were a perfect success in spite of the red colorations which are so poorly photogenic, as borne witness to below:

"The first photograph, reproduced above (Fig. 2) caught the sun near its setting in five successive exposures at intervals of about two minutes; we see plainly that there is absolutely no increase in size as the horizon is approached. The "disks become flattened, because of the refraction, in proportion as the sun sinks in the west, but the horizontal diameter remains the same. The dimension of the solar disk even appears to diminish as it descends because of its diminution in brilliance.

The second photograph (Fig. 3) represents the moon rising in the sky, and portrays itself as a path of uninterrupted light, extending to the top of the plate, in the apparatus, which remained open for two hours. We perceive that by a phenomenon analogous to the preceding, this path will seem rather to become wider because of the luminous intensity which increases with the purity of the atmosphere. There is also an effect due to the deformation introduced by the best objectives. The real image remains the same.

Conclusion: In reality the sun and the moon are not two or three times as large at the horizon as in the heights of the sky, though they appear to be; they are not even one fourth, one tenth, or any other fraction larger. The appearance is nothing but an optical illusion.

By reason of the parallax of the moon and of its considerably greater distance at the horizon than when it is at the zenith, by the entire length of the semi-diameter of the earth, it really shows itself as smaller at the horizon than at the meridian, in the proportion of a sixtieth or a half-minute of an arc. This variation is in the contrary direction to the apparent variation. It is not perceptible to our eyes.

It might be thought that our photograph bears evidence to this, for it here measures three millimeters below and three and one-half millimeters above, but I attribute this enlargement of the ribbon to the increase in the light of the moon in proportion as it rises in the sky. Is the apparent increase in size influenced by other causes than the geometrical form of the firmament?

The red coloration of the sun and the moon at the horizon, in contrast with the misty blue of the layers of air, the vague aspect of a semi-transparent atmosphere without precise limits, possibly play some part in this illusion[1].

Variations in the transparency of the air must play a non-negligible part, but always one of optical nature, producing contrasting effects upon our retina. Moreover, these variations may elongate the distance of the horizon, *i.e.*, flatten still more the celestial vault and *increase the apparent* size of the disks of the sun and moon at the horizon. The apparent changes in dimension and the difference of visibility may have still other causes.

Apropos of this, here is the letter I received from M. Saint-Saëns in the spring of 1911:

"My dear Flammarion: Excuse me if I till insist upon this question of the enlargement of objects near the horizon, by reason of observations which I have made upon this subject, every time I have had the opportunity, for a number of years.

"The flattened appearance of the vault of the sky explains perfectly, as you have said, the enlargement of the stars and constellations; but this appearance is not subject to variations; its effect should be always identical. But this is not the case. The enlargement observed is of variable nature. Hence there must be another cause which superposes itself upon that which you have so justly indicated.

"This cause is the effect of the 'magnifying glass' produced by the atmosphere under certain conditions, an effect which some hesitate to admit. These conditions, which remain to be determined, appear to me to be a special hygrometric state, a sort of transparent fog permitting objects to be clearly seen; but I cannot affirm the truth of this supposition. What I believe I can affirm is that the ordinary explanation is not sufficient in certain cases. It does not explain the enlargement of boats at a relatively short distance, and particularly why this increase in size is not always produced. It does not explain why it was that on one occasion, when I happened to be

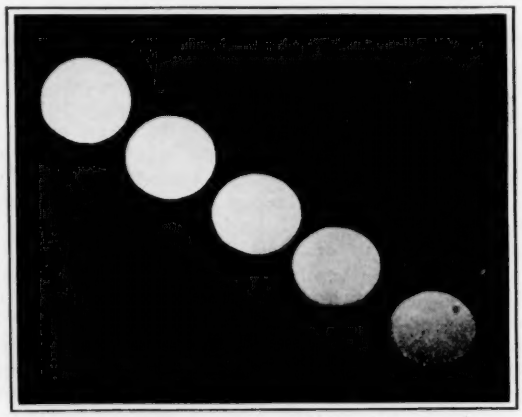


FIG. 2. THE SUN'S DISK PHOTOGRAPHED WHILE SETTING

on a boat in the Suez Canal, the City of Port Said seemed to all the passengers to be quite near because of the size of the buildings that compose it, but was suddenly reduced in volume and relegated to its true position.

"It does not explain how it was that one day, being on the shores of Lake Leman with two companions we suddenly saw an enormous grayish balloon ascend between two mountains, whose dimensions were so great and whose ascent was so rapid that it was three or four seconds before we recognized it to be the moon, whereafter it suddenly and markedly diminished in speed and dimensions.

"Finally, it does not explain why the moon, even at a considerable height above the horizon seems much larger on certain days than it usually does.

[1] See also what I wrote in the Bulletin for Nov., 1913, p. 500, as well as the quotation I have made fom Malebranche, 1912, pp. 489 and 539.

"An ignorant person like myself can only observe attentively and recount faithfully what he has seen. If he ventures, later, to risk the making of hypotheses, he may offer the excuse that some great savants have done the same and failed to have them confirmed by the facts. But he would be happy if he could instigate the savants to direct their attention to the phenomena which he has observed and themselves observe these with the competence which he himself lacks."

C. Saint-Saëns is too modest with respect to his own appraisal of himself, for we all hold him in high esteem; but he is, like us, capable of error, and we may remark, in answer to his first objection, that the appearance of the celestial vault *varies*.

Moreover, he invites the thought that the atmosphere at times plays an indeterminate rôle, and that in the Port Said case, for example, there may have been produced some effect of *mirage*.

We may also accept the views of Dr. Dubief with respect to the effects of binocular vision.

But so far as the enlargement of the stars is concerned

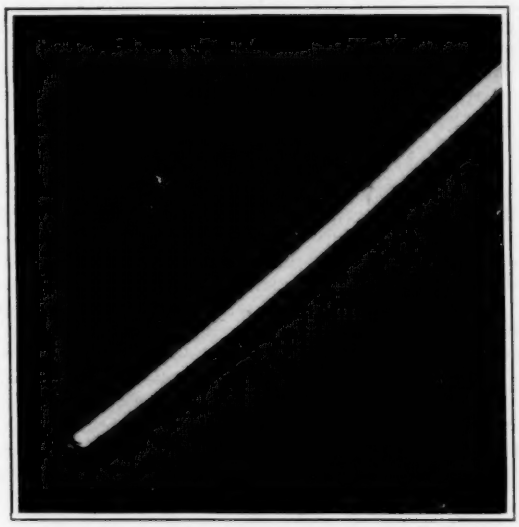


FIG. 3. PHOTOGRAPHIC PATH OF THE RISING MOON

it is certain that there is optical illusion. We do not really see the stars larger—we *believe* we see them larger. We deal here with a *psychological* fact, which is none the less interesting for our general instruction.

I recall that a few years ago a member of the *Société Scientifique Flammarion*, of Marseilles wrote to us that one evening in the port of that city, after having fixed his gaze upon the ruddy sun setting in splendor above the sea, he looked by chance at a point near the zenith—and perhaps taken as the zenith, according to the judicious remarks of M. Fouché—and that he was surprised, while seeing the blue complementary image clearly defined upon the vault of the sky, to note that it was only a half or a third as large as that of the red sun upon the horizon. Upon his retina, therefore, it did not possess the apparent dimensions.

Here is another image (Fig. 4) which confirms our reasoning. If we draw two equal circles in the interior of an angle, one near the apex, the other farther off the first will always appear the larger, because of the vicinity of the sides of the angle. The full moon, upon the horizon presents itself within the angle formed by the line of the earth and the apparent vault of the sky. The variations of this angle according to the aspect of the sky at the horizon may explain the variations in the apparent size of the moon at the time of its rise. But this is always an instance of optical illusion.

In my *Annuaire Astronomique* for 1913 I published, in the "*Scientific Recreations*," another sort of figure likeness showing the effects of an optical illusion (Fig. 5). Which is the longer, the distance between A and B, or that between C and D? It is exactly the same. If the former appears longer it is because the space between is empty.

These projections, for which I am indebted to our devoted

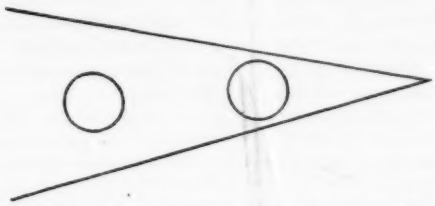


FIG. 4. AN OPTICAL ILLUSION. THE CIRCLE NEARER THE VERTEX APPEARS LARGER THAN THE OTHER

colleague, M. André Bloch, will make the latter, I believe, incontestably obvious to all eyes.

It appears to be definitely demonstrated, therefore, that the enlargement of the full moon and the sun at the time of rising and setting, as also that of the constellations at 20 or 30 degrees above the horizon, is nothing but an optical illusion.

One last objection: It has been said also that the sun and the full moon seem larger to us at the horizon simply because we see better that which is directly in front of us. Nearly everything which presents itself directly to our gaze diverges very slightly from the level of our eyes, and is situated at relatively small angular distances above or below the horizontal plane. Our visual faculty being highly developed in this direction the objects viewed thus appear larger than when seen in the other positions which they occupy with respect to our own.

This explanation may be disputed. A tree, fallen and lying upon the earth looks as large as when standing. The Eiffel Tower laid horizontally upon the ground, would seem even larger, for it would be necessary to walk 300 meters to traverse the whole extent. It is a question of the angle and the distance.

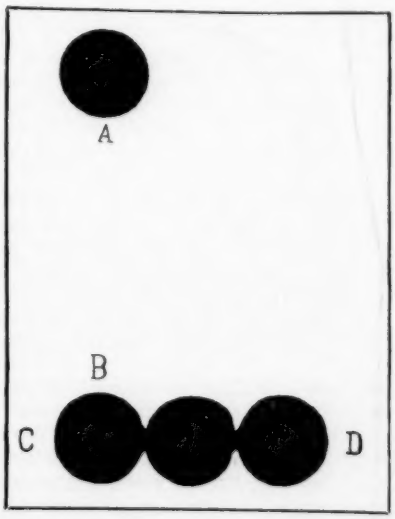


FIG. 5. ANOTHER ILLUSION IN WHICH THE EQUAL DISTANCES A B AND C D APPEAR UNEQUAL

In conclusion, therefore, we may say that the apparent form of the sky is sufficient by itself to explain the proportional enlargement of the stars and constellations upon their approach to the horizon.

Einstein's Relativity Theory of Gravitation*

A Popular Explanation

By E. Cunningham

THE results of the Solar Eclipse Expeditions announced at the joint meeting of the Royal Society and Royal Astronomical Society on November 6 brought for the first time to the notice of the general public the consummation of Einstein's new theory of gravitation. The theory was already in being before the war; it is one of the few pieces of pure scientific knowledge which have not been set aside in the emergency; preparations for this expedition were in progress before the war had ceased.

Before attempting to understand the theory which, if we are to believe the daily press, has dimmed the fame of Newton, it may be worth while to recall what it was that he did. It was not so much that he, first among men, used the differential calculus. That claim was disputed by Leibniz. Nor did he first conceive the exact relations of inertia and force. Of these, Galileo certainly had an inkling. Kepler, long before, had a vague suspicion of a universal gravitation, and the law of the inverse square had, at any rate, been mooted by Hooke before the "Principia" saw the light. The outstanding feature of Newton's work was that it drew together so many loose threads. It unified phenomena so diverse as the planetary motions, exactly described by Kepler, the everyday facts of falling bodies, the rise and fall of the tides, the top-like motion of the earth's axis, besides many minor irregularities in lunar and planetary motions. With all these drawn into such a simple scheme as the three laws of motion combined with the compact law of the invese square, it is no wonder that flights of speculation ceased for a time. The universe seemed simple and satisfying. For a century at least there was little to do but formal development of Newton's dynamics. In the mid-eighteenth century Maupertuis hinted at a new physical doctrine. He was not content to think of the universe as a great clock the wheels of which turned inevitably and irrevocably according to a fixed rule. Surely there must be some purpose, some divine economy in all its motions. So he propounded a principle of least action. But it soon appeared that this was only Newton's laws in a new guise; and so the eighteenth century closed.

The nineteenth saw great changes. When it closed, the age of electricity had come. Men were peering into the secrets of the atom. Space was no longer a mighty vacuum in the cold emptiness of which rolled the planets. It was filled in every part with restless energy. Æther, not matter, was the last reality. Mass and matter were electrical at bottom. A great problem was set for the present generation; to reconcile one with the other the new laws of electricity and the classical dynamics of Newton. At this point the principle of least action began to assume greater importance; for the old and the new schemes of the universe had this in common, that in each of them the time average of the difference between the kinetic and the potential energies appears to be a minimum.

One of the main difficulties encountered by the electrical theory of matter has been the obstinate refusal of gravitation to come within its scope. Quietly obeying the law of the inverse square, it heeded not the bustle and excitement of the ne wphysics of the atom, but remained, independent and inevitable, a constant challenge to rash claimants to the key of the universe. The electrical theory seemed on the way to explain every property of matter yet known, except the one most universal of them all. It could trace to its origins the difference between copper and glass, but not the common fact of their weight; and now the ether began silently to steal away.

One matter that has seriously troubled men in Newton's picture of the universe is its failure to accord with the philosophic doctrine of the relativity of space and time. The vital quantity in dynamics is the acceleration, the change of motion of a body. This does not mean that Newton assumed the existence of some ultimate framework in space relative to which the actual velocity of a body can be uniquely specified, for no difference is made to his laws if any arbitrary constant velocity is added to the velocity of every particle of matter at all time. The serious matter is that the laws cannot possibly have the same simplicity of form relative to two frameworks of which one is in rotation or non-uniform motion relative to the other. It seems, for instance, that if Newton were right, the term "fixed direction" in space means something, but "fixed position" means nothing. It seems as if the two must stand or fall together. And yet the physical relations certainly make a distinction. Why this should be so has not yet been made known to us. Whatever new theory we adopt must take account of the fact.

It was with some feeling of relief that men hailed the advent of the ether as a substitute for empty space, though we may note in passing that some philosophers—Comte, for example—have held that the concept of an ether, infinite and intangible, is as illogical as that of an absolute space. But, jumping at the notion, physicists proposed to measure all velocities and rotations relative to it. Alas! the ether refused to disclose the measurements. Explanations were soon forthcoming to account for its reluctance; but these were so far-reaching that they explained away the ether itself in the sense in which it was commonly understood. At any rate, they proved that this creature of the scientific imagination was not one, but many. It quite failed to satisfy the cravings for a permanent standard against which motion might be measured. The problem was left exactly where it was before. This was pre-war relativity, summarized by Einstein in 1905. The physicists complained loudly that he was taking away their ether.

Let it not be thought, however, that the results of the hypothesis then advanced were purely negative. They showed quite clearly that many current ideas must be modified, and in what direction this must be done. Most notably it emphasized the fact that inertia is not a fundamental and invariable property of matter; rather it must be supposed that it is consequent upon the property of energy. And, again, energy is a relative term. One absolute quantity alone remained; one only stood independent of the taste or fancy of the observer, and that was "action." While the ether and the associated system of measurement could be selected as any one of a legion, the principle of least action was satisfied in each of them, and the magnitude of the action was the same in all.

But, still, gravitation had to be left out; and the question from which Einstein began the great advance now consummated in success was this. If energy and inertia are inseparable, may not gravitation, too, be rooted in energy? If the energy in a beam of light has momentum, may it not also have weight?

The mere thought was revolutionary, crude though it be. For if at all possible it means reconsidering the hypothesis of the constancy and universality of the velocity of light. This hypothesis was essential to the yet infant principle of relativity. But if called in question, if the velocity of light is only approximately constant because of our ordinary ways of measuring, the principle of relativity, general as it is, becomes itself an approximation. But to what? It can only be to something more general still. Is it possible to maintain

*Reprinted from *Nature* (London).

anything at all of the principle with that essential limitation removed?

Here was exactly the point at which philosophers had criticized the original work of Einstein. For the physicist it did too much. For the philosopher it was not nearly drastic enough. He asked for an out-and-out relativity of space and time. He would have it that there is no ultimate criterion of the equality of space intervals or time intervals, save complete coincidence. All that is asked is that the order in which an observer perceives occurrences to happen and objects to be arranged shall not be disturbed. Subject to this, any way of measuring will do. The globe may be mapped on a Mercator projection, a gnomonic, a stereographic, or any other projection; but no one can say that one is a truer map than another. Each is a safe guide to the mariner or the aviator. So there are many ways of mapping out the sequences of events in space and time, all of which are equally true pictures and equally faithful servants.

This, then, was the mathematical problem presented to Einstein and solved. The pure mathematics required was already in existence. An absolute differential calculus, the theory of differential invariants, was already known. In pages of pure mathematics that the majority must always take as read, Riemann, Christoffel, Ricci, and Levi-Civita supplied him with the necessary machinery. It remained out of their equations and expressions to select some which had the nearest kinship to those of mathematical physics and to see what could be done with them.

THE NATURE OF THE THEORY.

We have attempted to show the roads which led to Einstein's adventure of thought. On the physical side briefly it was this. Newton associated gravitation definitely with mass. Electromagnetic theory showed that the mass of a body is not a definite and invariable quantity inherent in matter alone. The energy of light and heat certainly has inertia. Is it, then, also susceptible to gravitation, and, if so, exactly in what manner? The very precise experiments of Eötvös rather indicated that the mass of a body, as indicated by its inertia, is the same as that which is affected by gravitation.

Also, how must the expression of Newton's law of gravitation be modified to meet the new view of mass? How, also, must the electromagnetic theory and the related pre-war relativity be adapted to allow of the effect of gravitation? With the relaxation of the stipulation that the velocity of light shall be constant, will the principle of relativity become more general and acceptable to the philosophic doctrine of relativity, or will it, on the other hand, become completely impossible?

One point arises immediately. The out-and-out relativist will not admit an absolute measure of acceleration any more than of velocity. The effect, however, of an accelerated motion is to produce an apparent change in gravitation; the measure of gravitation at any place must therefore be a relative quantity depending upon the choice which the observer makes as to the way in which he will measure velocities and accelerations. This is one of Einstein's fundamental points. It has been customary in expositions of mechanics to distinguish between so-called "centrifugal force" and "gravitational force." The former is said to be fictitious, being simply a manifestation of the desire of a body to travel uniformly in a straight line. On the other hand, gravitation has been called a real force because associated with a cause external to the body on which it acts.

Einstein asks us to consider the result of supposing that the distinction is not essential. This was his so-called "principle of equivalence." It led at once to the idea of a ray of light being deviated as it passes through a field of gravitational force. An observer near the surface of the earth notes objects falling away from him towards the earth. Ordinarily, he attributes this to the earth's attraction. If he falls with them, his sense of gravitation is lost. His watch ceases to press on the bottom of his pocket; his feet no longer press on his boots. To this falling observer there is no gravitation. If he had time to think or make observations of the propagation of light, according to the principle of equivalence he would now find nothing gravitational to disturb the rectilinear motion of light. In other words, a ray of light propagated horizontally would share in his vertical motion. To an observer not falling, and, therefore, cognizant of a gravitational field, the path of the ray would therefore be bending downward towards the earth.

The systematic working out of this idea requires, as has been remarked, considerable mathematics. All that can be attempted here is to give a faint indication of the line of attack, mainly by way of analogy.

It is no new discovery to speak of time as a fourth dimension. Every human mind has the power in some degree of looking upon a period of the history of the world as a whole. In doing this, little difference is made between intervals of time and intervals of space. The whole is laid out before him to comprehend in one glance. He can at the same time contemplate a succession of events in time, and the spatial relations of those events. He can, for instance, think simultaneously of the growth of the British Empire chronologically and territorially. He can, so to speak, draw a map, a four-dimensional map, incapable of being drawn on paper, but none the less a picture of a domain of events.

Let us pursue the map analogy in the familiar two-dimensional sense. Imagine that a map of some region of the globe is drawn on some material capable of extension and distortion without physical restriction save that of the preservation of its continuity. No matter what distortion takes place, a continuous line marking a sequence of places remains continuous, and the places remain in the same order along that line. The map ceases to be any good as a record of distance travelled, but it invariably records certain facts, as, for example, that a place called London is in a region called England, and that another place called Paris cannot be reached from London without crossing a region of water. But the common characteristic of maps of correctly recording the shape of any small area is lost.

The shortest path from any place on the earth's surface to any other place is along a great circle; on all the common maps, one series of great circles, the meridians, is mapped as a series of straight lines. It might seem at first sight that our extensible map might be so strained that all great circles on the earth's surface might be represented by straight lines. But, as a matter of fact, this is not so. We might represent the meridians and the great circles through a second diameter of the earth as two sets of straight lines, but then every other great circle would be represented as a curve.

The extension of this to four dimensions gives a fair idea of Einstein's basic conception. In a world free from gravitation we ordinarily conceive of free particles as being permanently at rest or moving uniformly in straight lines. We may imagine a four-dimensional map in which the history of such a particle is recorded as a straight line. If the particle is at rest, the straight line is parallel to the time axis; otherwise it is inclined to it. Now if this map be strained in any manner, the paths of particles are no longer represented as straight lines. Any person who accepts the strained map as a picture of the facts may interpret the bent paths as evidence of a "gravitational field," but this field can be explained right away as due to his particular representation, for the paths can all be made straight.

But our two-dimensional analogy shows that we may conceive of cases where no amount of straining will make all the lines that record the history of free particles simultaneously straight; pure mathematics can show the precise geometrical significance of this, and can write down expressions which may serve as a measure of the deviations that cannot be

removed. The necessary calculus we owe to the genius of Riemann and Christoffel.

Einstein now identifies the presence of curvatures that cannot be smoothed out with the presence of matter. This means that the vanishing of certain mathematical expressions indicates the absence of matter. Thus he writes down the laws of the gravitational field in free space. On the other hand, if the expressions do not vanish, they must be equal to quantities characteristic of matter and its motion. These equalities form the expression of his law of gravitation at points where matter exists.

The reader will ask: What are the quantities which enter into these equations? To this only a very insufficient answer can here be given. If, in the four-dimensional map, two neighboring points be taken, representing what may be called two neighboring occurrences, the actual distance between them measured in the ordinary geometrical sense has no physical meaning. If the map be strained, it will be altered, and therefore to the relativist it represents something which is not in the external world of events apart from the observer's caprice of measurement. But Einstein assumes that there is a quantity depending on the relation of the points one to the other which is invariant—that is, independent of the particular map of events. Comparing one map with another, thinking of one being strained into the other, the relative positions of the two events are altered as the strain is altered. It is assumed that the strain at any point may be specified by a number of quantities (commonly denoted g_{rs}), and the invariable quantity is a function of these and of the relative positions of the points. It is these quantities g which characterize the gravitational field and enter into the differential equations which constitute the new law of gravitation.

It is, of course, impossible to convey a precise impression of the mathematical basis of this theory in non-mathematical terms. But the main purpose of this article is to indicate its very general nature. It differs from many theories in that it is not devised to meet newly observed phenomena. It is put together to satisfy a mental craving and an obstinate philosophic questioning. It is essentially pure mathematics. The first impression on the problem being stated is that it is incapable of solution; the second of amazement that it has been carried through; and the third of surprise that it should suggest phenomena capable of experimental investigation.

THE CRUCIAL PHENOMENA.

As Minkowski remarked in reference to Einstein's early restricted principle of relativity: "From henceforth, space by itself and time by itself do not exist; there remains only a blend of the two" ("Raum und Zeit," 1908). In this four-dimensional world that portrays all history let (x_1, x_2, x_3, x_4) be a set of coördinates. Any particular set of values attached to these coördinates marks an event. If an observer notes two events at neighboring places at slightly different times, the corresponding points of the four-dimensional map have coördinates slightly differing one from the other. Let the differences be called (dx_1, dx_2, dx_3, dx_4). Einstein's fundamental hypothesis is this: there exists a set of quantities g_{rs} such that

$$g_{11}dx_1^2 + 2g_{12}dx_1dx_2 + \ldots + g_{44}dx_4^2$$

has the same value, no matter how the four-dimensional map is strained. In any strain g_{rs} is, of course, changed, as are also the differences dx.§

If the above expression be denoted by $(ds)^2$, ds may conveniently be called the *interval* between two events (not, of course, in the sense of time interval). In the case of a field in which there is no gravitation at all, if dx_4 is taken to be dt, it is supposed that ds^2 reduces to the expression $dx_1^2 + dx_2^2 + dx_3^2 - c^2dt^2$, where c is the velocity of light. If this is put equal to zero, it simply expresses the condition that the neighboring events correspond to two events in the history of a point travelling with the velocity of light.

Einstein is now able to write down differential equations connecting the quantities g_{rs} with the coördinates (x_1, x_2, x_3, x_4), which are in complete accord with the requirement of complete relativity.[1] These equations are assumed to hold at all points of space unoccupied by matter, and they constitute Einstein's law of gravitation.

PLANETARY MOTION.

The next step is to find a solution of the equations when there is just one point in space at which matter is supposed to exist, one point which is a singularity of the solution. This can be effected completely:[2] That is, a unique expression is obtained for the interval between two neighboring events in the gravitational field of a single mass. This mass is now taken to be the sun.

It is next assumed that in the four-dimensional map (which by the way, has now a bad twist in it, that cannot be strained out, all along the line of points corresponding to the positions of the sun at every instant of time) the path of a particle moving under the gravitation of the sun will be the most direct line between any two points on it, in the sense that the sum of all the intervals corresponding to all the elements of its path is the least possible.[3] Thus the equations of motion are written down. The result is this:

The motion of a particle differs only from that given by the Newtonian theory by the presence of an additional acceleration towards the sun equal to three times the mass of the sun (in gravitational units) multiplied by the square of the angular velocity of the planet about the sun.

In the case of the planet Mercury, this new acceleration is of the order of 10^{-8} times the Newtonian acceleration. Thus up to this order of accuracy Einstein's theory actually arrives at Newton's laws: surely no dethronement of Newton.

The effect of the additional acceleration can easily be expressed as a perturbation of the Newtonian elliptic orbit of the planet. It leads to the result that the major axis of the orbit must rotate in the plane of the orbit at the rate of 42.9″ per century.

Now it has long been known that the perihelion of Mercury does actually rotate at the rate of about 40″ per century, and Newtonian theory has never succeeded in explaining this, except by *ad hoc* assumptions of disturbing matter not otherwise known.

Thus Einstein's theory almost exactly accounts for the one outstanding failure of Newton's scheme, and, we may note, does not introduce any discrepancy where hitherto there was agreement.

THE DEFLECTION OF LIGHT BY GRAVITATION.

The new theory having justified itself so far, it was thought worth while for British astronomers to devote their main energies at the recent solar eclipse to testing its prediction of an entirely new phenomenon.

As was remarked above, the propagation of light in the ordinary case of freedom from gravitational effect is represented by the equation $ds=0$.

This Einstein boldly transfers to his generalized theory. After all, it is quite a natural assumption. The propagation of light is a purely objective phenomenon. The emission of

§The gravitational field is specified by the set of quantities g_{rs}. When the gravitational field is small, these are all zero, except for g_{44}, which is approximately the ordinary Newtonian gravitational potential.

[1] These equations take the place of the old Laplace equation $\nabla^2 V = 0$. Just as that equation is the only differential equation of the second order which is entirely independent of any change of ordinary space co-ordinates, so Einstein equations are uniquely determined by the condition of relativity.

[2] The result is that the invariant interval ds is given by

$$ds^2 = (1-2m/r)(dt^2-dr^2)-r^2(d\theta^2+\sin^2\theta d\phi^2),$$

the four co-ordinates being now interpreted as time and ordinary spherical polar co-ordinates.

[3] This corresponds to the fact that in a field where there is no acceleration at all the path of a particle is the shortest distance between two points.

a disturbance from one point at another moment, are events distinct and independent of the existence of an observer. Any law that connects them must be one which is independent of the map the observer uses; ds being an invariant quantity, $ds=0$ expresses such an invariant law.

This leads at once to a law of variation of the velocity of light in the gravitational field of the sun.

$$v=c(1-2m/r).$$

Here m, as before, is the mass of the sun in gravitational units, and is equal to 1.47 kilometers, while c is the velocity of light at a great distance from the sun. Thus the path of a ray is the same as that if, on the ordinary view, it were travelling in a medium the refractive index of which was $(1-2m/r)^{-1}$. In this medium the refractive index would increase in approaching the sun, so that the rays would be bent round towards the sun in passing through it. The total amount of the deflection for a ray which just grazes the sun's surface works out to be 1.75″, falling off as the inverse of the distance of the nearest approach.

The apparent position of a star near to the sun is thus further from the sun's center than the true position. On the photographic plate in the actual observations made by the Eclipse Expedition the displacement of the star image is of the order of a thousandth of an inch. The measurements show without doubt such a displacement. The stars observed were, of course, not exactly at the edge of the sun's disk; but on reduction, allowing for the variation inversely as the distance, they give for the bend of a ray just grazing the sun the value 1.98″, with a probable error of 6 per cent, in the case of the Sobral expedition, and of 1.64″ in the Principe expedition.

The agreement with the theory is close enough, but, of course, alternative possible causes of the shift have to be considered. Naturally, the suggestion of an actual refracting atmosphere surrounding the sun has been made. The existence of this, however, seems to be negatived by the fact that an atmosphere sufficiently dense to produce the refraction in question would extinguish the light altogether, as the rays would have to travel a million miles or so through it. The second suggestion, made by Prof. Anderson in *Nature* of December 4, that the observed displacement might be due to a refraction of the ray in travelling through the earth's atmosphere in consequence of a temperature gradient within the shadow cone of the moon, seems also to be negatived. Prof. Eddington estimates that it would require a change of temperature of about 20° C. per minute at the observing station to produce the observed effect. Certainly no such temperature change as this has ever been noted; and, in fact, in Principe, at which the Cambridge expedition made its observations, there was practically no fall of temperature.

GRAVITATION AND THE SOLAR SPECTRUM.

It was suggested by Einstein that a further consequence of his theory would be an apparent discrepancy of period between the vibrations of an atom in the intense gravitational field of the sun and the vibrations of a similar atom in the much weaker field of the earth. This is arrived at thus. An observer would not be able to infer the intensity of the gravitational field in which he was placed from any observations of atomic vibrations in the same field; that is, an observer on the sun would estimate the period of vibrations of an atom there to be the same that he would find for a similar atom in the earth's field if he transported himself thither. But on transferring himself he automatically changes his scale of time; in the new scale of time the solar atom vibrates differently, and, therefore, is not synchronous with the terrestrial atom.

Observations of the solar spectrum so far are adverse to the existence of such an effect. What, then, is to be said? Is the theory wrong at this point? If so, it must be given up, in spite of its extraordinary success in respect of the other two phenomena.

Sir Joseph Larmor, however, is of opinion that Einstein's theory itself does not in reality predict the displacement at all. The present writer shares his opinion. Imagine, in fact, two identical atoms originally at a great distance from both sun and earth. They have the same period. Let an observer A accompany one of these into the gravitational field of the sun, and an observer B accompany the other into the field of the earth. In consequence of A and B having moved into different gravitational fields, they make different changes in their scales of time, so that actually the solar observer A will find a different period for the solar atom from that which B, on the earth, attributes to his atom. It is only when the two observers choose so to measure space and time that they consider themselves to be in identical gravitational fields that they will estimate the periods of the atoms alike. This is exactly what would happen if B transferred himself to the same position as A. Thus, though an important point remains to be cleared up, it cannot be said that it is one which at present weighs against Einstein's theory.

THE RESPONSE OF PLANTS TO WIRELESS STIMULATION*

By J. C. Bose.

A GROWING plant bends towards light; this is true, not only of the main stem, but also of its branches and attached leaves and leaflets. This movement in response is described as the tropic effect of light. Growth itself is modified by the action of light: two different effects depending on the intensity are produced; strong stimulus of light causes a diminution of rate of growth, but very feeble stimulus induces an acceleration of growth. The tropic effect is very strong in the ultra-violet region of the spectrum with its extremely short wave-length of light; but the effect declines practically to zero as we move towards the less refrangible rays, the yellow and the red, with their comparatively long wave-length. As we proceed further in the infra-red region we come across the vast range of electric radiation, the wave-lengths of which vary from the shortest wave I have been able to produce (0.6 cm.) to others which may be miles in length. There thus arises the very interesting question whether plants perceive and respond to the long ether-waves, including those employed in signalling through space.

At first sight this would appear to be very unlikely, for the most effective rays are in the ultra-violet region with wave-length as short as 20×10^{-6} cm.; but with electric waves used in wireless signalling we have to deal with waves 50,000,000 times as long. The perceptive power of our retina is confined within the very narrow range of a single octave, the wavelengths of which lie between 70×10^{-6} cm. and 35×10^{-6} cm. It is difficult to imagine that plants could perceive radiations so widely separated from each other as the visible light and the invisible electric waves.

But the subject assumes a different aspect when we take into consideration the total effect of radiation on the plant. Light induces two different effects which may broadly be distinguished as external and internal. The former is visible as movement; the latter finds no outward manifestation, but consists of an "up" or assimilatory chemical change with concomitant increase of potential energy. Of the two reactions, then, one is dynamic, attended by dissimilatory "down" change; the other is potential, associated with the opposite "up" change. In reality, the two effects take place simultaneously; but one of them becomes predominant under definite conditions.

The modifying condition is the *quality* of light. With reference to this I quote the following from Pfeffer:—"So far as is at present known, the action of different rays of the spectrum gives similar curves in regard to heliotropic and phototactic movements, to protoplasmic streaming and movements of the

* From *Nature* (London).

chloroplastids, as well as the photonastic movements produced by growth or by changes of turgor. On the other hand, it is the less refrangible rays which are most active in photosynthesis."[1] The dynamic and potential manifestations are thus seen to be complementary to each other, the rays which induce photosynthesis being relatively ineffective for tropic reaction, and *vice versa*.

Returning to the action of electric waves, since they exert no photosynthetic action they might conceivably induce the complementary tropic effect. These considerations led me to

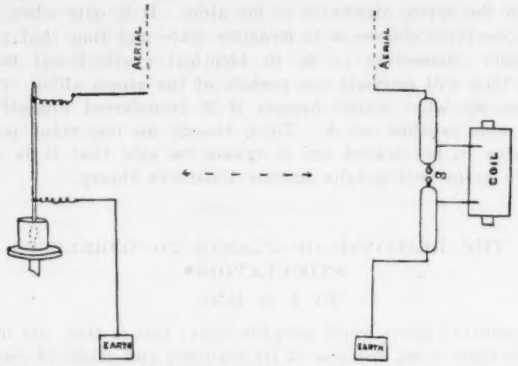


FIG.1. DIAGRAMMATIC REPRESENTATION OF THE METHOD OF WIRELESS STIMULATION

On the right is seen the generating apparatus. The tip of the growing plant is connected with the receiving aerial, and the lower part of the flower-pot is earthed.

the investigation of the subject fourteen years ago, and my results showed that very short electric waves induce a retardation of rate of growth; they also produce responsive movements of the leaf of Mimosa when the plant is in a highly sensitive condition.[2] The energy of the short electric waves is very feeble, and undergoes great diminution at a distance; hence the necessity for employment of a specimen of plant in a highly sensitive condition.

I resumed my investigations on the subject at the beginning of this year. I wished to find out whether plants in general perceived and responded to long ether-waves reaching them from a distance. The perception of the wireless stimulation was to be tested, not merely by the responsive movement of sensitive plants, but also by diverse modes of response given by all kinds of plants.

THE WIRELESS SYSTEM.

For sending wireless signals I had to improvise the following arrangement, more powerful means not being available. The secondary terminals of a moderate-sized Ruhmkorff's coil were connected with two cylinders of brass, each 20 cm. in length; the sparking took place between two small spheres of steel attached to the cylinders. One of the two cylinders was earthed and the other connected with the aerial 10 meters in height. The receiving aerial was also 10 meters in height, and its lower terminal led to the laboratory, and connected by means of a thin wire with the experimental plant growing in a pot; this latter was put in electric connnection with the earth (Fig. 1). The distance between the transmitting and receiving aerial was about 200 meters, the maximum length permitted by the grounds of the institute.

I may state here that with the arrangement described above I obtained very definite mechanical and electric response to wireless impulse. For the former I employed the plant Mimosa; the latter effect was detected in all plants, sensitive and ordinary. Limitation of space will allow only a detailed description of the responsive modification of growth.[3]

[1]Pfeffer, "Physiology of Plasts," vol. ii., p. 104.

[2]Bose, "Plant Response," p. 618 (1905).

[3]A detailed account of the response of plants to wireless stimulation will be found in the Transactions of the Bose Institute, vol. ii., to be published in November, 1919.

EFFECT OF WIRELESS STIMULATION ON GROWTH.

For the detection of variation of growth it was necessary to devise the extremely sensitive balanced crescograph. In this apparatus a compensating movement is given to the plant-holder by which the plant subsides exactly at the same rate as its growth-elongation, so that the tip of the plant remains at the same point. This perfect balance is attained by a variable regulator. The compound magnifying lever attached to the plant records the movement of growth. Under exact balance the record is horizontal. Any induced acceleration of growth would upset the balance, with a resulting down record; induced retardation, on the other hand, would cause an upset in the opposite direction and an up curve. The results given below show that growing plants not only perceive, but also respond to the stimulus of electric waves. These effects were found in all growing plants. The following records were obtained with the seedlings of wheat:

Effect of Feeble Stimulus.—Experiment 1: I first studied the effect of feeble stimulus. This was secured by decreasing the energy of sparks of the radiator. The response was an acceleration of rate of growth as seen in Fig. 2, (*a*). This is analogous to the accelerating effect of light stimulation of subminimal intensity.

Effect of Strong Stimulus.—Experiment 2: The maximum energy radiated by my transmitter, as stated before, was only moderate. In spite of this, its effect on plants was exhibited in a very striking manner. The balance was immediately upset, indicating a retardation of the rate of growth. The latent period *i. e.*, the interval between the incident wave and the response, was only a few seconds (Fig. 2, (*b*)). The record given in the figure was obtained with the moderate magnification of 2,000 times only; but with my crescograph the magnification can easily be raised ten million times, and

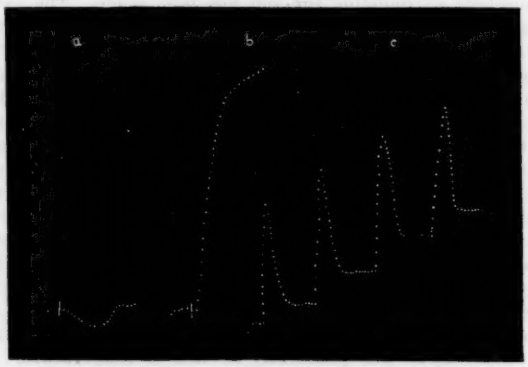


FIG. 2. AUTOMATIC RECORDS OBTAINED WITH THE BALANCED CRESCOGRAPH SHOWING THE EFFECTS OF WIRELESS STIMULATION ON GROWTH

(*a*) Feeble stimulus inducing acceleration; (*b*) strong stimulus inducing retardation of rate of growth; (*c*) series of growth responses by variation of growth due to uniform moderate stimulation. Up-curve represents retardation of growth and down-curve acceleration (seedling of wheat).

the perception of plant to the space-signalling can be exalted in the same proportion.

Under an intensity of stimulus slightly above the subminimal, the response exhibits retardation of growth followed by quick recovery, as seen in the series of records given in Fig. 2, (*c*). The perceptive range of the plant is inconceivably greater than ours; it not only perceives, but also responds to the different rays of the vast etheral spectrum.

PRESERVING EXPLOSIVES IN FRANCE

INSTEAD of storing her enormous stock of explosives (estimated value $140,000,000 to $150,000,000) in ordinary powder magazines and running the risk of disastrous explosions, France plans to submerge the stock in the cold lakes of the Pyrenees which are fed by glaciers.

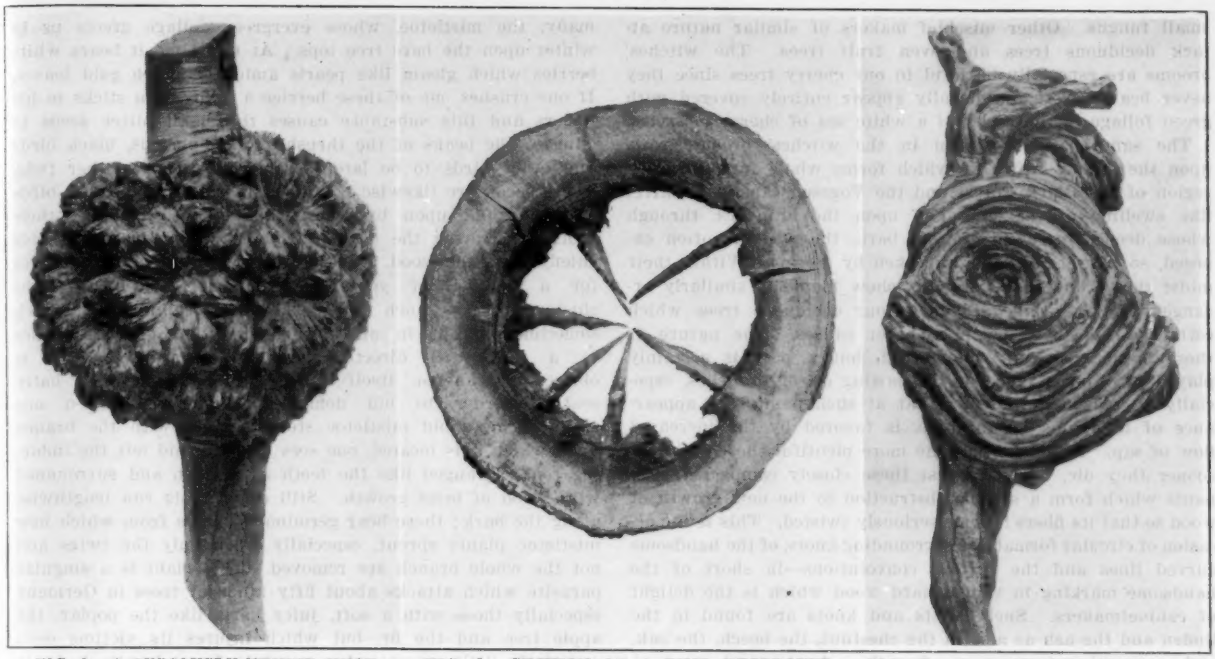


FIG. 1. A CURIOUSLY VEINED KNOT ON A BEECH BRANCH

FIG. 2. SECTION OF A PINE DESTROYED BY WHAT APPEAR TO BE INGROWING BRANCHES

FIG. 3. A ROSE-LIKE TUMOR ON THE ROOT OF A VINE

Singular Phenomena in the Kingdom of Plants

Curious Vegetable Deformities

By Dr. Bergner

WITH ILLUSTRATIONS FROM ORIGINAL PHOTOGRAPHS TAKEN BY THE AUTHOR

THE remarkable phenomena shown in the accompanying illustrations are rather more plentiful in nature than might be thought. Many such things in fact remain hidden from us merely because they escape our unpracticed observation. Even in our own homes we sometimes fail to perceive, until it is too late, what an evil guest we have been harboring when we see the boards of the walls stained with dirty white or brownish flecks like tufts of cotton wool and realize that the "weeping fungus" (the *Merulius lacrymans*, also called dry-rot) which has already infested the house is at last showing its face. And yet we might have known what was going on had we but observed that the walls which at first were dry had become damp and then sent forth an evil reek. It is, in fact, a peculiarity of the house fungus which starts to grow in dark, damp places and spreads throughout the timbers of a house and through thick layers of mortar, that it constantly conducts water by means of its fibrous filaments from damp places to those which are still dry. If we go down into the cellar with a lamp in a house so infested we shall see hundreds of drops of water sparkling upon the woodwork. These are the "tears" which proceed from the fungus and to which our own may well be added, for this devil in the form of a fungus has brought ruin upon many a house. Again in the garden we may see close pressed fungi springing from the ground round about a fruit tree and bursting the bark of the latter. This is the "Hallimasch" a most vexatious evil-doer although it is a very appetizing bit of food; it is easily recognizable by its smooth brown cap, convex in the middle and bearing scales covered with dark hairs, by the white gills, of its lower side and by the thickening of the stalk where it issues from the grouid. But when we perceive it, it has long had its filaments or hyphae sunk into the roots of the tree which it destroys and these same fibers also penetrate the stem, which often withers in a single year from this cause. But not content with this it reaches out to lay hold upon the neighboring trees, unless it is combated by the most thorough-going uprooting of the tree originally affected. This fungus is particularly injurious in forests of evergreen trees. It is the filaments of this fungus, too, spun throughout fallen trees that occasion a phosphorescent gleam from rotting wood. It is a marvellous sight to see the floor of the forest shining with countless particles of light when one's foot happens to strike such a bit of wood.

There are other fungi which lack stems which are even more destructive, transforming the wood into a sort of red brown mold. On this account this disease is known as "red rot" and it sometimes lays low a whole section of a forest, even of an extent of 10 ar. or more in scarce so many years. In the meanwhile a tree thus attacked continues to remain green for a long time until some day when the work of destruction has reached its maximum, it suddenly collapses. This is core rot—the pine trunk whose cross section is shown in Fig. 2, has fallen a victim to this disease. It is so striking in this instance that the branches have apparently turned inward, thus giving the impression of a wheel which lacks only the hub of the axle. Curious enough are the witches' brooms, which were once thought by common folk to represent an injury done the trees by those unholy dames who used to ride through the air towards the Hartz Mountains upon brooms. In the winter these resemble bushy brooms since in contrast to their hosts, the evergreen trees, they drop their yellowish green needles which encircle the twig. But the affected tuft continues to grow for many years longer, finally resembling a small separate tree, as shown in Fig. 4, springing from the bough. Such abnormal growths in the family of firs are due to a microscopically

small fungus. Other mischief makers of similar nature attack deciduous trees and even fruit trees. The witches' brooms are especially harmful to our cherry trees since they never bear flowers but usually appear entirely covered with green foliage in the midst of a white sea of cherry blossoms.

The same parasite shown in the witches' broom grows upon the stately white fir which forms whole forests in the region of the Black Forest and the Vogesen causing a barrel like swelling of the stem and upon the branches, through whose deeply furrowed cracked bark, the wood is often exposed, so that it rots and is broken by storms. Within their midst these cancer like growths show filaments similarly arranged like the veined knots of our deciduous trees which certainly owe their origin to other causes. The nature of these is not yet fully understood, but a part is certainly played by injuries, such as the sawing off of branches, especially by reason of the fact that at such points the appearance of numerous lateral buds is favored by the increased flow of sap. It is true that the more plentiful these buds the sooner they die, but it is just these closely compacted remnants which form a serious obstruction to the new growth of wood so that its fibers become seriously twisted. This is the occasion of circular formations surrounding knots, of the handsome curved lines and the curious convolutions—in short of the handsome marking in veined hard wood which is the delight of cabinetmakers. Such twists and knots are found in the linden and the ash as also in the chestnut, the beech, the oak, and many other trees; very often these knots partly or even entirely encircle the trunk and naturally rob the tree of much nourishment without, however, killing it. In many sorts of timber such knots are frequently found in the roots also, especially in those fruit trees bearing fruit with kernels, being occasioned sometimes in the first year of the tree's life through the cutting or bruising of the roots when the young tree is transplanted.

The most remarkable phenomena of this sort, however, is the "timber rose" (Fig. 5), which resembles a bit of carving done by the hand of an artist, but which is caused by the irritation produced by a tree parasite, the Loranthus which grows upon the fallen bough. This family, which is found abundantly in the tropics also has a representative in Germany, the mistletoe, whose evergreen foliage greets us in winter upon the bare tree tops. At this time it bears white berries which gleam like pearls amid the green gold leaves. If one crushes one of these berries a slimy gum sticks to his fingers and this substance causes the small bitter seeds to cling to the beaks of the thrushes, wood-pigeons, black birds and other birds to be later scraped off upon another twig. These seeds are likewise contained in the droppings of birds and thus fall upon branches where they germinate, their roots penetrating the bark and their scions drawing water chiefly from the wood. Mistletoe grows very slowly but lives for a number of years, so that it eventually forms clusters of as much as 4 m. in circumference, which sometimes sprout in an upward direction and sometimes in a downward direction from the branches. It is obliged to anchor itself most securely upon its hairy seat in order to bid defiance to storms. When one splits such an old mistletoe stem together with the branch upon which it is located, one sees to right and left the imbibing roots arranged like the teeth of a comb and surrounded with wood of later growth. Still other roots run lengthwise along the bark; these bear germinating buds from which new mistletoe plants sprout, especially when only the twigs and not the whole branch are removed. This plant is a singular parasite which attacks about fifty kinds of trees in Germany especially those with a soft, juicy bark, like the poplar, the apple tree and the fir, but which injures its victims comparatively little, except when a whole forest is attacked. It is rather to be regarded as a poor beggar struggling hard for existence and making use, even in the winter when other plants are resting, of every bit of light and heat, in order to transform the carbon abstracted from the air by its leaves and green forked twigs, into starch and sugar—in short it fights its way through life as honorably as possible. Its leathery foliage, which poachers employ to lure deer, forms excellent fodder, much craved by goats and cows, whose yield of milk it is said to increase. Whereas the growth and form of the mistletoe are limited by scantiness of space and of food supply, yet, on the other hand, it is true among plants, as well as among mankind, that too luxurious living results in deformities. Among such deformities belongs that

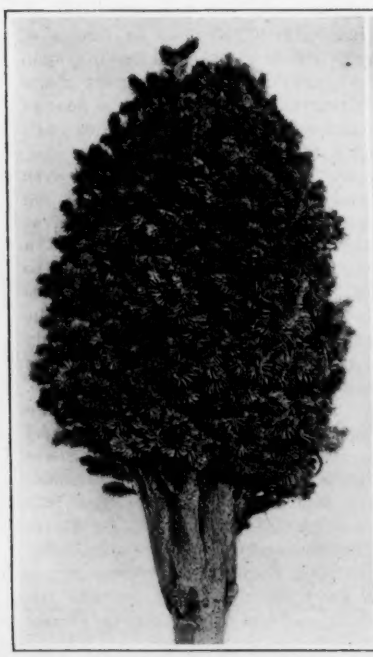


FIG. 4. A WITCHES' BROOM SHAPED LIKE A SMALL TREE. IT WAS FOUND ON A RED FIR

FIG. 5. MESSIANIC TIMBER ROSE ½ METER IN DIAMETER, CAUSED BY IRRITATION OF A PARASITE

FIG. 6. CURIOUS FLATTENING OF TWIGS OF A PINE PRODUCED BY LUXURIOUS LIVING

FIG. 7. GROWTH DUE TO EXCESS OF NUTRITION

FIG. 8. FASCIATED FORMATION OF THE MEADOW CRESS

FIG. 9. SECTION OF ROSE FUNGUS, NURSERY OF LARVAE

peculiar fascination which causes the twigs of a tree to be flattened as in the case of our pine (Fig. 6), or which may even cause the entire plant to take a ribbon-like form. At the same time the leaves and flowers are affected, either distributing themselves normally but irregularly or else crowning the summit in a very compact cluster. Who could recognize in the altered growth shown in Fig. 8 the ordinary meadow cress?

Such a deformity is favored by too rich fertilizing, especially in cases where the lateral twigs have been injured by the scythe or by the nibbling of animals so that the entire current of sap feeds the main shoot. This banding or ribbon-like form is frequently found, however, in cultivated plants and is also inheritable through the seeds as is seen in the case of the pretty garden flower known as the coxcomb, so called from the shape of its flowers. Such plants often grow very irregularly and curve themselves in the form of a sickle or of a bishop's staff, when the flat stem does not, indeed, split into separate bundles through too great a pressure of sap, these bundles rolling themselves up like a snail-shell. The remarkable piling up of tap roots at the base of an annual, which occurs especially in the pine (Fig 7) is also caused by an excess of nutrition. Instead of male blossoms numerous female ones appear, the little taps of which, however, yield fertile seeds. It is likewise true that "well-situated" flowers undergo alterations in a peculiar manner, not only through the fact that the calyx is transformed into flower petals, many of which are further advanced to the rank of stamens, . . . but still more strikingly in a decomposition of the flower into its parts. As a consequence of this the calyx is followed, separated by a large intermediate space, by the petals, then by the stamens in the next higher position, and finally, crowning the whole of the ovary with its pistil. Many garden lovers have probably also been struck by the curious fact that it sometimes happens that from the midst of a fragrant rose the flower axis extends bearing amidst green foliage a second rose, while this second rose, perhaps, is itself crowned by a bud through a similar extension of growth. A rose king! According to the popular notion this is an omen of happiness and sometimes of marriage when it is found in the spring of the year; when it appears in the autumn, however, it signifies misfortune, which, however, may be turned aside according to superstitious belief by plucking the messenger of evil secretly and silently and throwing it backward over one's shoulder. Of quite other origin, however, are the rose apples or "sleep apples," covered with green or red moss, which even today anxious rustic mothers put under the pillows of their little ones with the fond idea that they can thus protect the latter from cramps, or any other disturbance of their slumbers. These so-called "sleep apples" are in reality the nurseries of the tiny rose gall wasp, whose larvae one may find by cutting into such galls—the word gall being a collective name for this sort of formation (Fig. 9). These galls are legion, in fact, since the oak alone is attacked by 150 (more or less) different kinds of gall, each produced by small wasps or gnats. Among the best known of these are the green, red cheeked gall apples and the small lens-like bodies which are often found, even on the same oak leaf as the former, and which in many autumns cover the ground of the forest as thickly as if they had been scattered by the hand of the sower. Thus, the plant furnishes, probably because of the tiny drop of poison which enters its tissues when it is pierced and, perhaps, also, because of the irritation produced by the eggs and the larvae, not only nourishment to the intruders but also a comfortable residence to protect them—one of the most wonderful chapters in the history of nature!

A NEW VEGETABLE IVORY.

A RECENT number of the French Bulletin of the Colonial Office gives a description of a new form of vegetable ivory, which can be used in European industry in place of the coroso. This new substance is produced by the kernel of an edible fruit growing upon a palm of the upper Senegal-Niger territory, the *Borassus ethiapicum*. The kernel is 7 or 8 cm. long and 5 cm. broad, thus permitting the cutting of balls or plates of considerable size to be used in marquetry, or the making of dominoes, piano keys, buttons, etc. The kernel becomes extremely hard when thoroughly dried as a proof of this it is stated that it is at the present moment being used as building stones for the making of the houses of native chiefs, while it is expected that the future cathedral at Dakar will have tinted pillars constructed of these same kernels.

Efficiency of Aluminum Leaf on Airplane Propellers

Tests Conducted at the Forest Products Laboratory, Madison, Wisconsin

By A. C. Knauss*

WHEN varnishes and oil finishes are applied to furniture or cabinet work, not only are they expected to give it a pleasing appearance and to preserve the grain, but the belief is general that they prevent moisture from entering or leaving the wood. Commercial tests to determine whether varnish is water-proof consist of immersing varnished pieces of wood in water and noting the change in the color of the varnish. Varnishes which do not turn white under such tests are pronounced water-proof. Spar varnishes have shown the least tendency to turn white under such a test.

Experience during the war showed that a water-proof coating was an important factor in keeping airplane propellers serviceable. Propellers not given a water-proof covering changed their moisture content with varying atmospheric

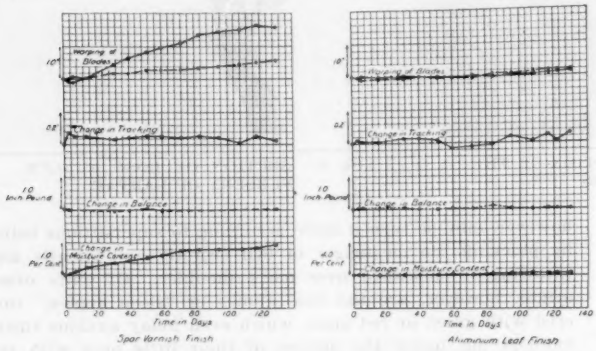


FIG. 1. CURVES SHOWING WARPS OF PROPELLERS PROPELLERS CHANGED FROM 60 PER CENT RELATIVE HUMIDITY TO 90 PER CENT RELATIVE HUMIDITY AT 80° F.

conditions and consequently warped, lost balance, went out of track, or changed the sizes of the hub holes so that they would neither fit properly nor give satisfaction when put into service. Linseed oil proved ineffective in preventing these changes, and even after spar varnish was used propellers still went "bad" rapidly and the number of rejections was large. In order to eliminate any factors which might cause changes of shape in propellers, manufacture was subjected to rigid inspection, and close matching of material and conditioning to uniform moisture content was insisted upon more and more.

A laboratory for making experimental propellers for the United States Army and Navy and for trying out various propeller coatings was established at the Forest Products Laboratory, Madison, Wis. Many propellers were made up of selected and conditioned material. Others were made of kiln-dried stock on a production schedule. After being carved out, these propellers were given protective coatings of spar varnish or of aluminum leaf. The spar varnish coating was that commercially used for propellers*, while the aluminum leaf was a coating developed at the Forest Products Laboratory. It consists of sheets of beaten aluminum foil, applied to a tacky varnish surface. Enamel or varnish is applied over the leaf to protect it from mechanical wear. After being given these finishes, the propellers were placed in rooms in which the atmosphere was controlled to approximate climatic conditions in war zone sectors. The propellers were weighed and measured at frequent intervals to determine the water-proofing ability of the coatings, and, if the moisture content changed, to determine how seriously the blades would warp or the propeller lose its balance. Over 250 propellers of seven different species of wood have been made and are being given these climatic tests.

In Fig. 1 are shown the results obtained on two propellers which were made under favorable manufacturing conditions but given different finish coatings. The wood, quarter-sawed northern red oak, was carefully kiln-dried, matched for uniform density and conditioned to uniform moisture content before being glued up into propeller blocks. After roughing out, these blocks were stored for a month in a room held under uniform conditions before they were carved out to final shape. During this period conditions within the propeller reached equilibrium and any warping accompanying internal changes would be cut away in the final shaping.

One of these propeller was given a spar varnish finish, the other an aluminum leaf finish. Both were then placed in a room in which the temperature was continually held at 80° F. and the relative humidity at 60 per cent. When the measurements showed that both propellers were remaining unchanged in shape or weight, they were moved to a room in which the relative humidity was held at 90 per cent and the temperature at 80° F.

The propeller covered with spar varnish absorbed moisture rapidly, and the blades warped a corresponding amount. At the end of 30 days it had increased 1.6 per cent in moisture content and one blade had warped enough to cause the rejection of the propeller from service. After having been in the humid atmosphere for 130 days, the moisture content had increased by 4 per cent and one blade had warped 1.6 degrees, four times the error permitted in manufacture, while the other had also warped beyond the prescribed tolerance. The moisture failed to penetrate the covering of aluminum leaf, however, and the second propeller weighed practically the same after 130 days of test as it did at the beginning. Its blade angles remained unchanged, and its tracking and balance were within the limits set for manufacture.

The results on these two propellers were substantiated by the results on all other propellers made under similar conditions. Spar varnish was clearly shown to be an ineffective water-proofing agent, although it retards the absorption of moisture to a great extent.

The same grade of spar varnish finish was applied to practically all airplane propellers made in the United States and sent to France for service, therefore they were as subject to moisture changes as these test propellers. Propellers in service in France normally have a moisture content from 6 to 8 per cent higher than that at which propellers are manufactured in the United States. After reaching France American-made propellers would ultimately increase in moisture content by this amount, and would warp more severely than the varnished test propellers. When moisture changes are prevented, as in the case of the propeller covered with aluminum leaf, practically no warping or change in shape takes place. While the tendency of the wood in the propeller would be to increase from 6 to 8 per cent in moisture content the aluminum leaf would effectively prevent such an absorption of moisture.

These first two propellers had been made of selected material, carefully kiln-dried and conditioned before manufacture, the efficiency of aluminum leaf in making propellers water-proof was further tested on two propellers made under unfavorable conditions. Rejected material, flat-sawed red oak, which was checked because of improper kiln-drying, was glued up, without previous conditioning, into two propeller blocks. After being carved out, both propellers were given

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[1]Standard specifications—U. S. Air Service.

an aluminum leaf finish. Almost immediately this finish was cracked by the checks which were formed in the wood during the process of moisture equalization. After being covered with aluminum leaf, the cracks opened again. The propellers were finally placed in testing rooms, one in a warm, dry room, the other in a warm, moist room. Figures 2 and 3 show the behavior of these propellers during the test. The blades of both propellers changed somewhat during the first days of the test. After approximate equilibrium was reached, however, they remained well within the tolerance throughout the remainder of the 300 days. Both propellers remained within the tolerance for tracking of blades after the internal stresses were equalized, and one propeller remained in balance throughout the test, while the other developed a slight lack of balance.

Since the initial warping of the blades was not accompanied by a change in moisture content it was undoubtedly the result of conditions within the wood which were not allowed to come

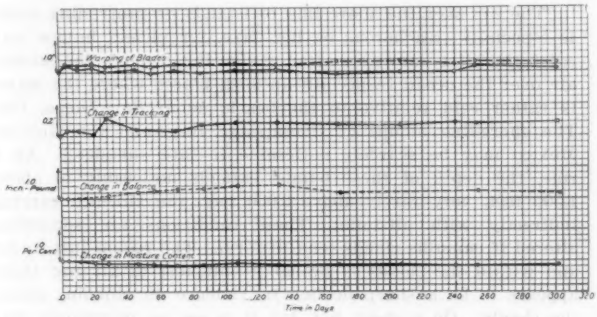


FIG. 2. BEHAVIOR OF PROPELLER WITH ALUMINUM LEAF FINISH SUBJECTED TO 90 PER CENT RELATIVE HUMIDITY AT 80° F.

to equilibrium before the propellers were carved. After approximate equilibrium was reached the propellers remained nearly constant in shape and balance. That the aluminum leaf was effective in preventing the absorption or giving off of moisture by the propellers is shown by the fact that in spite of the cracks the change in moisture content was small. Had the propellers been placed in these rooms without a finish, the difference in moisture content between the two would have reached 9 or 10 per cent. After 300 days of test, however, the total difference in moisture content was only 2 per cent. Had the coating of leaf remained intact, this difference would have been much less.

These two propellers were manufactured under conditions less favorable than would ordinarliy occur in commercial production. Although they warped and changed somewhat, they did not exceed, with one or two exceptions, the manufacturing tolerance.

While spar varnish has been shown by these tests to be rather ineffective as a water-proof covering when applied to propellers, aluminum leaf has shown an extraordinary ability to resist the transmission of moisture, and to protect propellers effectively from external moisture conditions. Even when made under unfavorable conditions and of rejected material, propellers covered with aluminum leaf did not warp enough to become unserviceable when subjected to extreme climatic conditions. Propellers made under favorable conditions and covered with aluminum leaf gave very slight indications of warping or other defects.

The cost of covering propellers with aluminum leaf is no greater than for spar varnish, while the time required can be reduced to two-thirds of that necessary for applying the spar varnish. The weight of leaf is insignificant; less than one-thirtieth of an ounce, costing about fifty cents, entirely covers a propeller.

The aluminum leaf coating is as capable of resisting wear in service as in spar varnish finish. While the leaf may soon be worn off when once the propeller is put into service, it will keep the propeller true to shape during transit and storage, thus insuring the flyer a serviceable propeller when it reaches him, while one covered with spar varnish may be twisted enough to be rejected. Furthermore it would be as simple a matter to repair the aluminum leaf coating as the spar varnish. In any event, the life of a propeller in service is usually short compared with the time spent in transit and storage.

As has been shown in the case of the two propellers made of rejected material, aluminum leaf cannot be used to hide unreliable manufacturing methods. Changes in shape are certain to follow such methods. If aluminum leaf were used it would be entirely practical to devise specifications with smaller tolerances and thus secure a better finished product, with the assurance that the propeller would remain within this tolerance for a long time after leaving the factory.

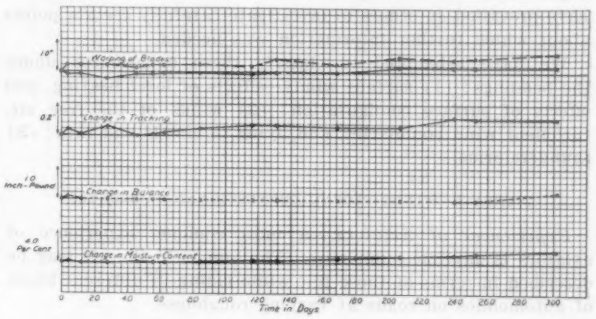


FIG. 3. BEHAVIOR OF PROPELLER WITH ALUMINUM LEAF FINISH SUBJECTED TO 30 PER CENT RELATIVE HUMIDITY AT 80° F.

It can be quite safely said, then, that the aluminum leaf covering is in all respects as good and in most respects much better than spar varnish. Compared with spar varnish, aluminum leaf lasts as long in service, its cost of application is no greater, the time required for finishing is reduced by one-third, and as a water-proofing agent it has shown itself to be immensely superior.

PROPOSED WATERWAY FROM THE ADRIATIC TO THE BLACK SEA

ITALY is seriously concerned over the shortage of coal. The English markets, whence she has heretofore obtained the bulk of her fuel, are partially closed and in this extremity she is forced to look elsewhere for obtaining the equivalent of the 33,000 tons of coal at present required every month for maintaining her industrial activity.

It has therefore been suggested that steps should be taken to utilize the Danube for connecting up the Adriatic with the Black Sea, thus assuring to Italy an adequate supply of liquid fuel from the oil fields of Rumania and those bordering the Black Sea and in the Basin of the Caspian. The so-called Adriatic-Black Sea Line would follow the course of the Danube from the Black Sea to Belgrade, where it would branch off up the Save as far as the confluence of the River Kulpa.

From this latter point, two routes are possible, viz.: by rendering navigable either the upper course of the Save from Sissek to Lubiana, or the Kulpa from Sissek to Venice. A third method of getting over this final section would be by canalizing the Drave from Marburg to Klagenfurt and Villacco, and connecting up the valleys of the Drave and the Upper Tagliamento by a new canal. (Padus, *L'Italia sul Mare*, Nov., 1919. Abstracted through *The Technical Review*.)

"Bumpiness" in Flying*

Effects of Winds and Other Weather Conditions on the Flight of Airplanes

By Charles Brooks and Others

IN a mutual discussion of the meteorological aspects of aviation the aviator and the meteorologist obtain much valuable information. The aviator tells the meteorologist his experiences with various air conditions, and the meteorologist attempts to explain how such conditions are produced, how best to avoid the unfavorable ones, and how to take advantage of the favorable. Furthermore, the information which the aviator can give the meteorologist helps to explain many doubtful weather phenomena which the meteorologist has not been able to observe personally at close range. To obtain facts essential for this paper, about 50 experienced aviators have been consulted. In several cases Signal Corps meteorologists themselves have made flights or have prevailed on others to investigate carefully certain points about which further information was needed.

We have attempted to classify these experiences under the headings: (1) surface winds—effects of local heating, and effects of surface configuration; (2) winds of the free air, turbulent wind boundaries, and flying in clouds and rain; (3) thunderstorms.

SURFACE WINDS—LOCAL CONVECTIONAL CURRENTS.

Experiences of Aviators.—A most common experience of aviators is daytime bumpiness. The bumps in the air may be described in terms of those felt while riding in different kinds of automobiles on roads af varying roughness.

The aviator may be experiencing moderate bumps and suddenly encounter one sharp enough to "throw the fire extinguisher into my lap" or to "set the ship nearly up on end." Then there may be a little more smooth flying until suddenly the support seems to disappear, the propeller appears to give no headway, and down goes the airplane. A bump may announce the bottom, and the aviator slowly climbs again to his proper level. As seen from the ground on a "bumpy" day, the airplane tilts from side to side to a maximum of 30° from the horizontal, and now and then some sharp up or down motion is discernible. The tilts may give the ship a side slip, which will sometimes be sufficient to remove it from one side of a V formation to the other. When such a side slip occurs too near the ground, one of the airplane accidents characteristic of a hot day in the South occurs.

In general, there appear to be differences of opinion among pilots. All say that for ordinary bumps a change of 50 feet is common. A change of 200 feet is experienced at times, and occasionally an aviator comes in with a story of having risen or fallen 500 feet. The larger and faster the airplane the less is the change of altitude due to bumps. Most of the aviators say that unless flying in formation, it is impossible to tell the amount of up or down motion with a bump or in a "hole" without watching the altimeter.

Most bumps in the air occur near the ground and on bright, hot days. In the northeastern United States, 3,000 to 5,000 feet is the upper limit of bumpiness on a summer day, though in very hot weather, bumpiness, sometimes extreme, occurs at elevations even above 8,000 feet. In Texas the air is bumpy sometimes to more than 10,000 feet. In winter the usual limit of bumpiness at Ellington Field, Texas, is 1,500 to 2,000 feet. Ordinarily, however, the extremely bumpy conditions are within 500 to 2,500 feet of the ground or just under and about cumulus clouds.

The places where bumps occur are well known to aviators. Roads, railroads, edges of plowed fields, forest edges and clearings, barn roofs, hangars, ditches, borders of swamps, shore lines, all give bumps, the sources of which can be identified generally to 700 or 800 feet, and on calm days occasionally to 2,500 and even 3,500 or more feet. The bumps associated with macadam roads and other hot places are not necessarily directly over the road, but to leeward at a distance depending on the velocity of the wind and the height of the airplane. Some aviators at Rich Field allowed for fall of about 15 feet in crossing a sunken road in the vicinity of the field. Railroads have the same effects as roads. Creeks seem to have down currents over them.

As to conditions along the coast, the following statement by Donald B. Kimball, a naval aviator, shows the effect of difference in convection over water and land surfaces:

"The air over the shore line of islands or protruding necks is especially treacherous on hot days, for violent bumps may catch the pilot unawares after navigating through the smooth air over the ocean [especially in such places where the water is rather cold relative to the beach, as at San Diego, Cal. The shore-line bumps of Chesapeake Bay, and the Gulf of Mexico may be scarcely noticeable in late summer.] As a rule, the depth of these bumps extends noticeably to about 1,500 feet, very rarely above 2,000 feet, the violence varying indirectly with altitude. These conditions are somewhat altered if cumulus clouds tend to form. The region just under and within the clouds is probably bumpiest of all and there appears to be a sharp decline in violence on climbing above the clouds. On a clear, hot day it is not an uncommon feat for a perfectly balanced machine to fly several minutes at altitudes under 1,000 feet without having the foot controls moved. On such a day I once even saw a pilot step from the front seat to the wing and thence to the rear seat at an altitude of about 75 feet. Such a feat would be almost suicidal in land flying on a hot day."

Explanation of Bumpiness.—The local vertical currents which occur on warm days are the result of the unequal heating of the lower air. The air next to the ground gets hot; and, therefore, expands. Over a bare, dry field the heating is greatest. Thus, the surface air locally may become considerably lighter than the cooler air at the same level or even above; and so at the first opportunity some of this heavier air moves laterally or comes down and forces some of the lighter air to rise. On a quiet day at the earth's surface the movement of this cooler air is marked by light, variable winds interspersed with calms. The process of displacement is intermittent. When there is a wind blowing, the occasions when the cooler air moves toward the warmer places are marked by gusts or slack wind. These gusts are the result not only of the combined strength of the horizontal components of convectional winds and of the general wind, but also of the quick, down movement of air, which has a higher velocity than the friction-limited wind next to the ground.

The reason for the bumpier conditions in the middle of the day and for the greater bumpiness in Texas than elsewhere is now apparent—the hotter the lower air relative to that above, the stronger are the convectional currents and the gustier the wind. The reason for the decrease in bumpiness aloft is that near the earth there are likely to be the steepest temperature and wind velocity gradients. Again, the upper limit of bumpiness is the upper limit of the convectional columns of detached masses of rising air; and in much of Texas, at least, the tops of the convectional upcurrents are marked almost daily by the tops of cumulus clouds. (Cf. Figs. 1 and 2.) The locations of bumps over roads, railroads, plowed fields, open spots in woods, etc., depend on the differences in the degree of heating of different parts

*Abstracted from the *Monthly Weather Review.*

of the landscape. The road gets hotter than the fields on either side, and so the air from both sides flows toward, and displaces upward, the air over the road. (A, Fig 1.) Plowed fields are likewise hotter than the surrounding fields, because their dark, loose surfaces absorb so much more heat, and conduct downward so much less heat, than the surfaces of unplowed fields. Open woods favor bumpiness because some parts become hotter than others. (B, Fig. 1.)

Isolated hills, especially short or conical ones, should be avoided during warm, still days, for on such occasions their sides are certain to be warmer than the adjacent atmosphere

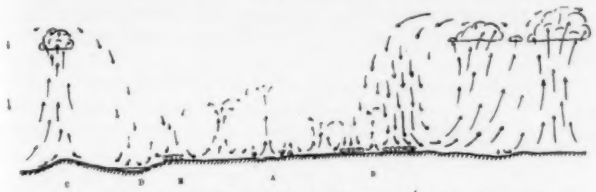


FIG. 1. LOCAL CONVECTIONAL CURRENTS ON CALM DAY.

at the same level and hence to act like so many chimneys in producing updrafts. (C, Fig. 1.)

The rising currents are interesting, not only because of the way in which they disturb airplanes, but also because they may be utilized by aviators who are trying to make altitude in the shortest time. Many use a rising air column that forms the cumulus, but they claim that many accidents have occurred because of the uncertainties of its direction and action. An aviator who has flown over an active forest fire never does so again, if possible.

Down currents, marking the movement of relatively cool air over ponds (D), lakes, and clumps of trees (E, Fig. 1), do not have the marked velocity of upward currents, but are more dangerous. Their boundaries may be sharp enough for an airplane to fly with one wing in and one wing out of the descending current.

EFFECT OF TOPOGRAPHY ON WINDS.

The effects of heating and cooling of the earth's surface upon the flow of air is not the only cause of turbulence, for there is the effect of topography, which introduces phenomena quite as dangerous and distressing to the airman as convection.

Aviators' Experiences.—Roughnesses (including trees and buildings) of the surface produce eddy motion, which in a moderate wind will reach to 1,000 or 2,000 feet and in a strong wind to 3,000 feet or more.

During a gale the edge of the woods near Houston, Texas, is marked to a height of 1,000 or more feet. Bad bumps have been felt 2,500 feet above and to leeward of hangars on a windy day.

Neumen reports that on days with high winds in eastern Maryland "the air [up to 10,000 feet] seems to be moving in great horizontal eddies or rolls similar to the rolling of ocean waves. The air plane rocks just like a rowboat in the sea."

Many pilots have been questioned regarding the effect of topography upon the action of their planes at various altitudes. In addition to the natural configurations of the ground, there are also the effect introduced by buildings. groves of trees, and other obstacles over which the wind must pass. The general opinion is that these effects do not extend upward nearly so far as strong convection does, except, perhaps, in very rough mountainous country or with winds of gale force. It appears also that the altitude to which such disturbances may extend is proportional in general to the wind velocity and the size of the surface irregularities.

Lieutenant S. W. Addison says when passing over buildings, groves of trees, or similar obstacles bumps are generally experienced, their extent being influenced mainly by the strength of the wind. As obstacles of this character are approached with a following wind the machine will lift and drop with equal suddenness on the other side. If approached head to wind the converse will take place—the machine will probably drop, sometimes nearly to the ground, just before reaching the obstacle, and rise as it leaves it. This seems to be due to the fact that when the wind strikes the obstacle it shoots upward. (Fig. 2.) It would be difficult to say what height this updraft generally reaches, but the writer's experience is that it goes up well above the actual height of the obstacle, and is "flattened out" on the other side, where there is often an unmistakable down current.

The turbulence caused by hills or mountains depends largely on the local topography and on the winds concerned. Point Loma, near San Diego, Cal., gives birth to marked turbulent conditions over and to leeward of it.

An aviator flying at 3,500 to 4,000 feet inland from San Diego with the wind, passed over some mountains 2,000 feet high. On the lee side he was forced down, or fell, 1,500 feet. The prevailing cloud sheet at 4,000 feet gave from below no notable indication of such a current, but it seems probable that the upper surface would have shown where the wind was up and where down. The upper surface of this "velo" (stratus) cloud sheet is usually uneven; but this aviator on other occasions had not happened to find how to tell from the form of the cloud surface the underlying topography.

The air over a mountain region is usually turbulent. Capt. F. N. Bartlett, in a flight from Scott Field, Ill., to Kelly Field, Tex., a year ago had nine hours of difficult flying over the Ozarks between Eberts Field, Ark., and Post Field, Okla. This turbulence attendant upon flying over the Ozarks was strongly manifest in a recent balloon trip from Fort Omaha, in which it was desired to maintain a constant elevation of 5,000 feet above sea level. This was found absolutely impossible and the balloon often was dragged down to within a short distance of the ground, or caused to ascend again, almost out of the control of the pilot. The accompanying balloon at 10,000 feet was but little affected. On windy days over

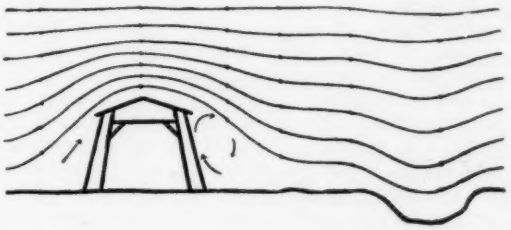


FIG. 2. EFFECT OF MINOR SURFACE IRREGULARITIES ON LINES OF WIND FLOW IN A LIGHT WIND. (FROM LINKE.)

rough topography, bumpiness has been generally observed to 4,000 feet.

Lieut. R. O. Searles, the flight commander of the De Haviland squadron, which made the trip from Ellington field to the Pacific coast and back, related that on the 24th and 26th of February, 1919, it was not possible to enter the Grand Canyon with a plane, but that it was easily possible on the 25th. Sergt. E. B. Scott indicates this was doubtless due to the pressure distribution on those dates, for on the 25th the gradient wind was not of great speed and, moreover, conformed with the direction of the canyon, whereas on the preceding and following days the pressure gradient was steeper and the wind direction was such as to produce great turbulence in passing across the canyon. It has been reported that in a strong south wind the back-and-up current of the eddy in the lee o fthe south wall of the canyon has carried tin cans up the cliff and into the yard of the hotel.

Interpretations.—Wind Eddies.—"Just as eddies and whirls exist in every stream of water, from tiny rills to the great rivers and even the ocean currents, wherever the banks are

such as greatly to change the direction of flow, and wherever there is a pocket of considerable depth and extent on either side, and as similar eddies but with horizontal instead of vertical axes occur at the bottom of streams where they flow over ledges that produce abrupt changes in the levels of their beds, so too, and for the same general reasons, horizontal eddies occur in the atmosphere with rotation proportional, roughly to the strength of the wind. These are most pronounced on the lee sides of cuts, cliffs, and steep mountains; but also occur, to a less extent, on the windward sides of and above large obstructions."[1]

"The inertia of the wind crossing the mountains tends to carry it on well above the valley or plain beyond, but its drag on the yower air, due to viscosity, deflects it downward. (Fig. 3.) Because of this deflection a foehn wind often strikes the lower slopes with great violence, from which, and mainly because of its dynamical heating, it rebounds to higher levels. Along a belt, therefore, well down the mountain, or even slightly beyond its base, the surface wind may be exceedingly turbulent and violent, while both farther away and also on the higher slopes it is comparatively light. Furthermore, owing to changes in the general direction of the crossing current, or in its strength, or both, the wind belt may shift up or down the mountain or even vanish entirely."—*W. J. Humphreys.*

"The air at the top and bottom of wind whirls is moving in diametrically opposite directions—at the top with the parent or prevailing wind, at the bottom against it—and since they are close to the earth they may, therefore, be a source of decided danger to aviators. There may be some danger also at the forward side of the eddy where the downward motion is greatest.

"When the wind is blowing strongly landings should not be made, if at all avoidable, on the lee side of and close to steep mountains, hills, bluffs, or even large buildings, for these are the favorable haunts, as just explained, of treacherous vortices. The whirl is best avoided by landing in an open place some distance from bluffs and large obstructions, or, if the obstruction is a hill, on top of the hill itself. If, however, a landing to one side is necessary, and the aviator has a choice of sides, other things equal, he should take the *windward* and not the *lee* side. Finally, if a landing close to the lee side is compulsory, he should if possible head up the hill with *sufficient velocity* to offset any probable loss of support due to an eddy current in the same direction. He could, of course, avoid loss of velocity with reference to the air, and therefore loss of support, by heading along the hill, that is, along the axis of the vortex, but this gain would be at the expense of the dangers incident to landing in a side or cross wind. His only other alternative, heading down the hill, might be correct so far as the direction of the surface wind is concerned, but it probably would entail a long run on the ground and its consequent dangers.

"Eddies of a very different type, relatively small and so turbulent as to have no well-defined axis of rotation, are formed, as is well known, by the flow of strong winds past the side or corner of a building, steep cliff, and the like. In reality such disturbances are, perhaps, more of the 'breaker' type, presently to be explained, than like a smoothly flowing vortex, and should be avoided whenever the wind is above a light breeze.

"Clearly, the support to an airplane flying either with or against a wind of this kind is correspondingly erratic, and may vary between such wide limits that the aviator will find himself in a veritable nest of 'holes' out of which it is difficult to rise, at least with a slow machine, and sometimes dangerous to try. However, as the turmoil due to the horizontal winds rapidly decreases with increase in elevation, and as the aviator's safety depends upon steady conditions, or upon the velocity of his machine with reference to the atmosphere and not with reference to the ground, it is obvious that the windier it is, the higher, in general, the minimum level at which he should fly."[1]

Effect of gusts.—Aside from the obvious effects of vertical currents, already discussed, the mere changes of velocity in a horizontal direction that accompany the passage of gusts tend to produce an up-and-down motion in an airplane flying with or against the wind. If the airplane is flying with the wind, any increase in the velocity of the wind will momentarily reduce the support of the airplane, thereby causing it to drop, while any decrease in velocity will momentarily increase the air speed of the machine, tending to make it rise. The reverse is the case if the machine is going against the wind.

This is because in a steady wind an airplane itself moves as if in a calm. Thus if the wind is unsteady the number of gusts encountered in a given time will be the same whether

FIG. 3. WIND CROSSING A RIDGE. (FROM CLOUD MOVEMENTS OBSERVED ALONG THE HUDSON RIVER, AUGUST 4, 1918.)

there is a following or a head wind. And if, as the anemometers indicate, gusts have no more abrupt onset than end, the effect of a gust from in front or of a lull from behind should be the same. Nevertheless, aviators say they can feel the difference between a head wind and a following one, and that they climb fastest against the wind. Soaring birds have the same experience. This would seem difficult to explain in any other way than that gusts begin more suddenly than they end. Apparently, we need more refined observation to show what the difference is.[2]

Effect of gustiness on a turning airplane.—Probably the chief disturbance due to gusty wind—excessive tipping and side slipping—occurs not during straightaway flying but as the aviator turns at low levels from flying against the gusts to flying with them.

WINDS OF THE FREE AIR: TURBULENT WIND BOUNDARIES.

The difficulties of the pilot do not cease once he has risen above the turbulence of the lower air produced either by local convectional currents or by the tumbling of the wind over the surface of the earth. There are numerous accounts by aviators which tell of wind boundaries which are entirely invisible.

"Ordinarily there is not more than 100 feet of turbulence on wind boundaries. The boundary separating two winds is easily noted by the great disturbance, and bumpiness, the violence of which depends on the velocity of the winds. In many instances the change of winds will be just above where the cloud layer is forming or slightly above the haze."—*E. M. Powers.*

"*Wind layers.*—For one reason or another it often happens that adjacent layers of air differ abruptly from each other in temperature, humidity, and density, and therefore, as explained by Helmholtz, may and often do glide over each other in much the same manner that air flows over water, and with the same general wave-producing effect. These air waves are seen only when the humidity at the interface is such that the slight difference in temperature between the crests and the troughs is sufficient to keep the one cloud capped and the other free from condensation. In short, the humidity condition must be just right. Clearly, then, though such clouds often occur in beautiful parallel rows, adjacent wind strata of different velocities and their consequent air billows must be of far more frequent occurrence.

[1]Humphreys, W. J. "Winds Adverse to Aviation," etc., manuscript enlarged from paper published as Chapter IV, in a Manual of Aerography for the United States Navy, 1918.

[2]Abstract from C. C. Turner, *Aeron. Journ.* (London) **22**: 285-6, 1918.

"This fact is abundantly proved by all types of aerological work, as well as by all those who ascend into the air. Kite balloons in ascending are often seen to rotate, pointing their noses in various directions, indicative of various wind directions at different levels, yet there may be no cloud layer at the interface to mark it. Free balloonists make use of these layers of air, which may have different directions and speeds in order to aid them in achieving whatever result they seek, such as distance or a given destination."[1]

"*Wind billows.*—When one layer of air runs over another of different density billows are set up between them, as is often shown by windrow clouds. However, the warning clouds are comparatively seldom present, and therefore even the cautious aviator may, with no evidence of danger before him, take the very level of the air billows themselves, and before getting safely above or below them encounter one or more sudden changes in wind direction and velocity due, in part, to the eddy-like or rolling motion within the waves, with chances in each case of being deprived of a portion of the requisite sustaining force. There may be perfect safety in either layer, but, unless headed just right, there necessarily is some risk in going from one to the other. Hence, flying at the billow level, since it would necessitate frequent transitions of this nature, should be avoided.

"When the billows are within 300 meters (1,000 ft.), say, of the earth (often the case during winter owing to the prevalence then of cold surface air with warmer air above) they are apt to be very turbulent, just as, and for much the same reason, that, waves in shallow water are turbulent. For this reason, presumably, winter flying sometimes is surprisingly rough. Fortunately, however, it is easy to determine by the aid of a suitable station barograph whether or not billows are prevalent in the low atmosphere since they produce frequent (5 to 12 per hour roughly) pressure changes, usually of 0.1 mm. to 0.3 mm. at the surface."[1]

CLOUDS AND RAIN.

Flying in clouds or above them is the choice of the aviator over enemy territory more than over friendly country. How the aviator in the United States feels toward the clouds is well shown by the classification of the weather conditions under which the postal aviators between Washington and New York have to fly. In succession these are—ideal, fair, occasional clouds, frequent clouds, high winds, thick clouds, thick clouds and high winds, rain storms, combination of storms and heavy fogs. Clouds are generally avoided because one cannot see where he is going nor keep right side up. Cumulus clouds, particularly those with hard-looking outlines, are avoided because of their bumpiness, coldness and fogginess; also, not infrequently because they have falling rain. Such clouds are usually roughest and wettest at their bases. A full account of "Danger in flying through clouds," by Capt. B. C. Huchs, was presented to the Aeronautical Society of Great Britain, and reprinted in SCIENTIFIC AMERICAN SUPPLEMENT, June 15, 1918, page 375.

Strato-cumulus clouds and cumulus clouds with fuzzy edges have weaker ascensional currents and are less bumpy to fly through. Aviators in flying about such cumulus clouds can easily lop off corners and even make small clouds evaporate by flying through them. Some cumuli have cavities 1,000 feet high in their bases.

Flying in the rain is avoided, if possible. Even in midsummer in Texas, at 7,000 feet in the air, an aviator flying through a rain cloud felt so cold that he described the rain drops as "ice particles." The impact of rain drops is sufficient to make them feel solid. On this occasion, there was a considerable collection of water on the airplane. The weight of rain water can hardly affect the performance of the airplane much, unless the drops freeze on. In the spring of 1918 an aviator in Texas had such an experience during a shower; he flew up into a cloud until at 7,000 feet his airplane had become so covered with ice that he could go no higher. The effect of rain on the propellor is destructive. The propeller moves at such a high velocity that unless specially protected the rain drops cut it as if they were bullets.

Aside from the general unpleasantness of flying in rain, the water may cause faulty engine action by getting into the carburetor and the ignition system. As to general turbulence within clouds, there is very little definite information from aviators because the propeller so violently churns up the air in the neighborhood, and this mixing is often sufficient to mask any real small-scale turbulence that may exist there.

THUNDERSTORMS.

In thunderstorms, however, these turbulent conditions are of considerably greater magnitude, and are, in fact, so violent that great danger is entailed in flying in or about them. Indeed, few aviators have flown into a thunderstorm and come out alive.

Experiences.—Lightning is one danger. About August 1, 1918, an aviator flew into a thunderstorm at Paxton, Ill., and was found dead, with lightning burns on his body. Another aviator a year earlier, thinking apparently that the thunder storm was going with the lower wind flew into the storm and was killed. Several years ago a flyer named Ehrmann had his machine set on fire by lightning, but he escaped unhurt.[2]

Capt. Cave says:[4] "It is possible that danger from lightning to an airplane flying through a thunderstorm may be no more than that incurred by a pedestrian walking across an open common during a storm. A pilot who was flying above a thunderstorm last summer reported that long sparks were given off by his machine at intervals. It is very likely that this happened every time there was a flash of lightning from the cloud below him."

Aviators in the United States have also experienced such discharges while flying in thunderstorms or through gaps between thunderheads.

The *turbulence* within a thunderstorm is awful to experience.

"A French machine was called upon to ascend during a violent thunder and windstorm for important observation work over the German lines. When at a height of several thousand feet the members of the squadron below saw the turret and its machine gun stripped from the craft by the gale.

"The observer's seat was next to go, but the occupant, grasping the wing stays, clung to the sailing plane. The craft was whipped about in the sky at will and the cloth completely stripped from the fuselage. Both pilot and observer were clinging to their broken craft when it reached the earth after a series of gyrations rivaling the most daring acrobatics practiced by the Allied aces. Both occupants escaped serious injury."[5]

It is quite likely that in such cases pilots and observers think very little of thunderstorm structure or the meteorological aspects of the situation.

Many aviators have experienced the great up-current which occurs on the front of the squall wind issuing from the base of a thunderstorm. Ascents of several thousand feet have been reported not only in Texas but also in Florida. Two of the most striking ones, both from Texas, will be cited. On one occasion, near Fort Worth, the aviators began to return to Carruthers Field on the approach of a thunderstorm. Lieut. Morgan on banking for a turn while just over the squall front was suddenly lifted from 2,000 to an elevation of 7,000 feet, a rise of 5,000 feet in almost no time. He thought that his altimeter had "gone crazy." On descending immediately he reached the field just before the squall struck it. Other aviators were lifted similarly by 2,000 to 4,000 feet. Those that landed after the "50-mile" squall began had to land with their propellers going full speed.

[2]C. C. Turner, "The Romance of Aeronautics," page 229, Philadelphia, 1912.

[4]Cave, C. P. J. Some meteorological conditions which increase the danger of flying *Aero. Jour.* (London), 1917, vol. 21, p. 301.

[5]W. S. Forrest, New York *Tribune* report, July 14, 1918.

In the other instance, Lieut. Cobb was "stunting" near Love Field at about 3,500 feet altitude during the approach of a thunderstorm. After doing three evolutions, taking about 15 minutes, he found that he had gained some 3,500 feet in altitude, instead of losing 1,500 feet, as was usual. Sometimes the lifting would be of the order of 500 feet in a minute. This indicates that there was a wind with an average vertical component upward at about 5 miles per hour (2 m/s) blowing toward the storm, an upward rate quite to be expected under such circumstances. At the end, the aviators noticed sharp mammato-cumulus above and strato-cumulus clouds below them. They seemed to be at an altitude about midway between them, though they were some 5 miles away from the

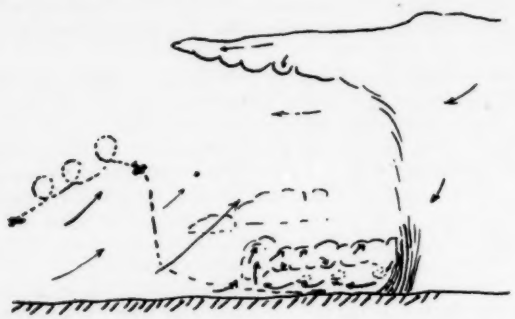


FIG. 4. WINDS EXPERIENCED ON THUNDERSTORM FRONT NEAR LOVE FIELD, TEX., FROM DESCRIPTION BY LIEUT. COBB

storm front. On descending they soon entered extremely bumpy air and were able to land only by diving into the wind with the engine on (Fig. 4). The rain began immediately after that. Landing in thunder squalls presents considerable difficulty. Once an aviator above such a squall, in the opposite return current, headed into the wind and made a descent to the field. He did not observe that the surface wind was opposite in direction. As he approached the landing place he noticed that for some reason he was not losing speed, and when only 5 feet from the ground saw that he was going with the wind. He was moving so fast that he went 4 miles before getting sufficient elevation to turn and come back.

Interpretations.—The air movements about thunderstorms, in the lower level at least, seem to be relatively simple. The heavy fall of rain and the coolness of the air under a thunderstorm produce a down-flow of air which spreads laterally in the form of a squall. The squall wind is stronger than the forward rate of advance, and so there is a considerable rate of ascent on the front; and the cold squall wedge also forces up the warm general wind. The air which goes down from a thunderstorm is supplied by a return flow of low velocity above the squall. (Fig. 4.) This return takes place above 1,000 or 2,000 feet and is probably strongest at 3,000 feet or higher. In the front of the squall the presence of obstructions will locally increase the rate of ascent of the air, especially when such obstructions are in the lee of a flat area. The extraordinary up-current near Fort Worth, referred to above, occurred just in the lee of Lake Worth. An airplane in the rain under the thunderstorm is likely to be carried down not only by the weight of the rain but also by the downflow of the air. An airplane in the squall itself is likely to be disturbed by eddies. An aviator who wants to go around a thunderstorm will find the fastest going at a height of about 2,000 feet, between the outflowing wind below and the inflowing one above.

AIR DENSITY CHANGES AS AFFECTING SUPPORT.

On cold days with high atmospheric pressure an airplane has little difficulty in "taking off." For example, Capt. H. H. Storrer cites an instance when with the barometer at 30.67 inches and the temperature 30° F. "one could ascend at a fair rate with the elevators in the position usually employed in horizontal flights; this, of course, in calm air."

On hot days or at altitudes of a few thousand feet, on the contrary, the rarefied air often makes it difficult to rise from the ground. Aviators at Kelly Field, Tex., and Fort Sill, Okla., have noticed repeatedly that on very hot days there was difficulty in taking off, due to the rarefied air. More striking than this, however, is the case of failure of the propeller to "take hold" in the rare air of higher elevations. Lieut. Nutt, of Ellington Field, Tex., accustomed to the distance required to take off in low elevations, failed to take into account the fact that a greater distance would be required at a higher elevation, and at Denver, Colo., October, 1918, crashed into a fence in consequence.

Not only are these difficulties noticed in taking off, but also are they troublesome in landing, for the plane continues to roll along the ground for an unusual distance before coming to a stop. Landing fields at relatively high elevations should be larger than those near sea level and also at their edges should be free from obstructions like telephone and power lines, which might be permitted at lower levels.

CONCLUSION.

From the accounts of the numerous exciting experiences aviators have because of the conditions of the air, it is obvious that the more meteorology an aviator knows the better he can handle himself in the air, other things being equal. Furthermore, it is evident that the airplane has opened to the professional meteorologist a new and potent means of investigating the phenomena of the air. Much can be surmised from careful observations of cloud movements taken from the ground; but how much more satisfactory it is to be able to fly up and investigate personally, what is happening!

The *Weather Bureau* would be glad to receive accounts of unusual flying experiences ascribable to weather or air conditions.

TAUTOMETER FOR TESTING DOPED SURFACES.*

THE power of tautening varies with different dopes; hence the necessity for the tautometer, which should measure the degree of tautness brought about by the particular dope or covering employed. Until recently the tautness was simply more or less guessed, the method usually adopted being to merely tap the doped fabric and deduce the tautness from the note produced. The higher the note, the greater the tautening power of the dope was assumed to be.

The function of a tautometer is to measure the effect of a depressing force, usually exerted by applying a known weight to the center of a known area of doped fabric. This tautness determination is a measurement of at least two important factors of the dope, *i. e.*, the tension of state of strain given to the doped fabric and the flexibility of the dope film.

The method of tapping has proved to be both inaccurate and misleading. For instance, a hard film is frequently obtained when an acetyl dope is employed and the doped fabric sounds tauter than measurement with a reliable tautometer proves it to be. In reality a high note frequently indicates a hard and brittle film which will have a great tendency to crack on exposure.

There are various types of instruments for measuring tautness now in use; one, for example, consists of a heavy round-bottomed framework, having a pivot through the center attached to a spring on the upper side, which, in turn, is connected with a pointer. Except for a knob fixed to the lower end of the pivot, only the outer rim of the round bottom of the instrument touches the doped fabric. This instrument is placed on the frame to be measured, and according to the tautness of the doped fabric the knob at the end of the pivot is pushed upward to a greater or less extent, thus

*From *The Jour. of the Soc. of Automot. Eng.*

compressing the spring and moving the pointer to a position which may be read off on a circular scale. This instrument has many disadvantages, the chief of which is that the tautness of only the small portion of the doped fabric enclosed by the rim of the instrument is measured. Also, the whole weight of the tautometer rests on the doped fabric, and that is obviously no small factor in its disfavor.

The tautometer shown is based on the principle of a balance with a 10 to 1 beam or any other convenient ratio, so that the deflection of the long arm *a* can be magnified for a slight depression of the other *b*. The beam is suspended on a knife-edge in the ordinary way, except that the support is connected with a screw *c* which is used to adjust the beam to any height required. This screw also serves to fix the whole apparatus to a framework *d* which fits over the frame to be measured in such a way that the specified weight, 400 g. having been adopted in the case of the instrument described, is suspended from the short arm, exactly over the center of the frame. This weight is compensated by a 40-g. weight *e* in the scale pan, suspended from the long arm *a*.

When this tautometer is placed on a frame the reading of the pointer at the end of the long run should be at zero on the curved scale *g*, attached to the framework at the right side. If this is not the case the necessary adjustment can be effected by turning the screw *c* in the direction required either to raise or lower the beam. When this has been done the 40-g. weight should be removed from the scale pan. This causes the 400-g. weight *g*, which till now has been just touching the surface, to rest on the doped fabric, and the depdession due to it can be read off by the pointer and scale at the other side. This curved scale can conveniently be divided into graduations representing millimeter or fractional parts of an inch depressions of the 400-g. weight on the doped fabric.

The 10 to 1 beam has the advantage of causing a perceptible deflection of the pointer for only 1-mm. depression of the weight, and it must be understood that the smallest deflections are caused by the tautest frames.

A simple adaptation on the same principle has also been used for much larger frames and might with advantage be employed for airplane wings. In this case all framework is dispensed with, except for the bracket used in supporting the knife-edge *a* of the beam *b*. This is

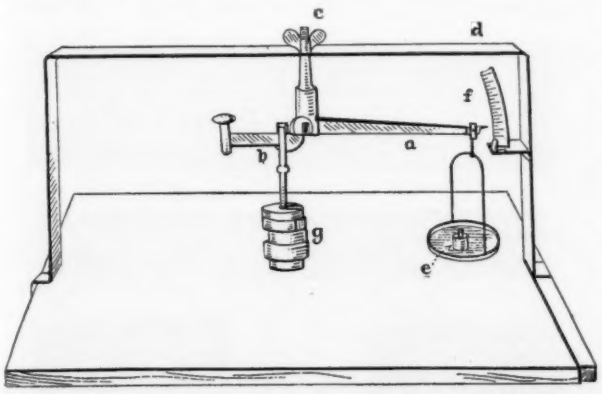


FIG. 1. A TAUTOMETER FOR TESTING SMALL PORTIONS OF A DOPED SURFACE, WHICH EMPLOYS THE PRINCIPLE OF A BALANCE WITH A RATIO OF LEVERS THAT PROVIDES FOR A MAGNIFICATION OF ANY DEPRESSION OF THE SHORT ARM

fixed to the wall at a convenient height and should stand out half-way across the frame *o* of the wing to be measured, so that the weight to be used for determining the tautness can be arranged to touch the center of the frame. The beam itself should be counterpoised, as before, so as to give a long arm and a short one, when in equilibrium on the knife-edge. Then, as in the previous case, a heavy load is suspended from the short arm to test the tautness of the doped fabric, but instead of having the compensating weight in a scale pan, a sliding weight *d* has been adopted, which is placed directly on the beam. When a reading is taken, the weight is slid from the marked position of equilibrium *e* to another one *f* nearer the knife edge, so calculated

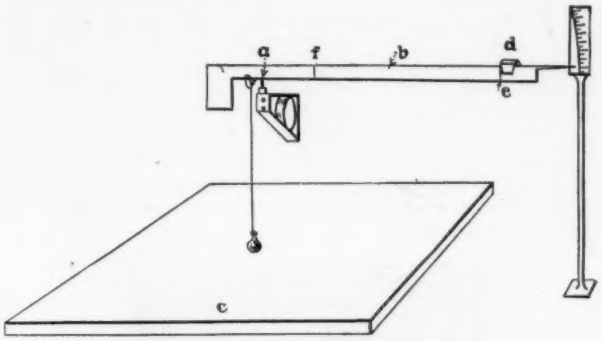


FIG. 2. AN ADAPTATION OF THE SAME PRINCIPLE THAT IS CAPABLE OF USE IN THE TESTING OF LARGE FRAMES AND AIRPLANE WINGS

as to allow the necessary load to rest on the doped fabric. The reading of the pointer on the curved scale can then be noted as before, to show the depression of the doped fabric caused by the weight of the load.

RECOVERY OF NITRE AND PITCH FROM "SMOKE CANDLES."

E. R. THOMAS.

AMONG the various duties of an ammunition officer in the field is that of the disposal of dangerous and unserviceable ammunition.

Those stores such as "ground flares" (consisting of shellac and nitrates) and "smoke candles" (pitch and potassium nitrate) which depend for their efficiency on the dryness of the priming composition used for their ignition, are particularly liable to deterioration on exposure.

The author was horrified to find that the unserviceable flares and smoke candles were being burnt or dumped in the English Channel with a considerable expenditure of time and labor. Although he had been advised to conceal his knowledge of chemistry—advice not without its point—he set out to find some simple method for recovery of the pitch and potassium nitrate from the smoke candles. This was soon elaborated, and with the aid of a band of Chinese coolies, over a ton of pitch and nearly a ton of potassium nintrate were produced daily.

The methods were crude. The extraction was done in Soyer stover, and the crystallization in unserviceable cartridge cylinders. The stirrer was part of a broken ammunition box, and the fuel was waste wood from the same source. After all expenses were met, the work resulted in a profit of at least £20 a day.

The pitch was mixed with sand and used as a substitute for timber for flooring purposes. The work was also carried out at two convalescent camps where the labor cost was nil. In both places large "physical training huts" were completely floored with material from the recovered pitch. The potassium nitrate was stored and ultimately returned to England.

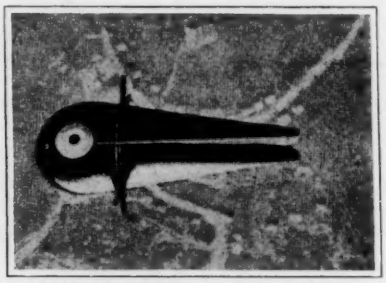
The success of these operations led to their authorization and extension to many classes of unserviceable ammunition previously dumped in the Channel.—Abstracted by the *Journal of the Society of Chemical Industry* from a paper read before the British Association for the Advancement of Science, September, 1919.

The Great Problem of Landing*

Its Bearing on the Future of Aviation

OF the many problems asking for the ingenuity of flight enthusiasts the landing problem is in all ways the biggest, because it is a subject for invention, and because it carries with it the complete future of aviation. Wild opinions are being given regarding air brakes, extended surfaces, extraordinary speed variations, etc., etc., but the fact that you must land and start appears to be lost sight of.

Flying is easy—dead easy—and any fool can manage a machine in the air; but to start a real high-speed machine and to land it is a problem exceeding the wit of the thing called man at the present time.



A FLYING MACHINE OF THE FUTURE

Look at so-called facts. Flight is possible, according to the scientific experts, up to the speed of sound, say, roughly, up to 1,000 miles per hour. The present ratio between flight and landing speed is about 3 to 1—*i. e.*, you can fly at 150 m.p.h. and land at 50. In other words, looking at the future, you can fly at 1,000 m.p.h. and land at 330 m.p.h. *It can't be done.*

Is any improvement on this ratio possible? Well, say there is, and give the improvement as 25 per cent, making the landing speed 250 m.p.h. You still can't do it, or even look at it. If air brakes will improve it by 10 per cent and extended surfaces by 10 per cent, you are still faced with a landing speed of some 250 m.p.h.!

What is the alternative? Several may be suggested, but none can be put as tried. To make an efficient flying machine the landing gear must be omitted—that goes without saying. The landing gear in a modern machine amounts to some 10 per cent of the total head resistance, and *this ratio will increase.* It follows, arguing from first principles, that both landing and starting must be done by means outside and separate from the machine itself.

The starting should not be too extraordinary. Armstrong-Whitworth's, of Newcastle, made a good catapult years ago, and I have seen this throw a 2-ton machine into a speed of 60 m.p.h. at a length of 60 feet. There is no great snag here. You can start the machine. But the stopping is different, and it takes a wise man to lay down rules for it. The obvious, the entirely simple solution, is a wind tunnel, wherein the wind speed equals the flying speed of the machine. That is obvious; but the expense of this scheme is equally obvious.

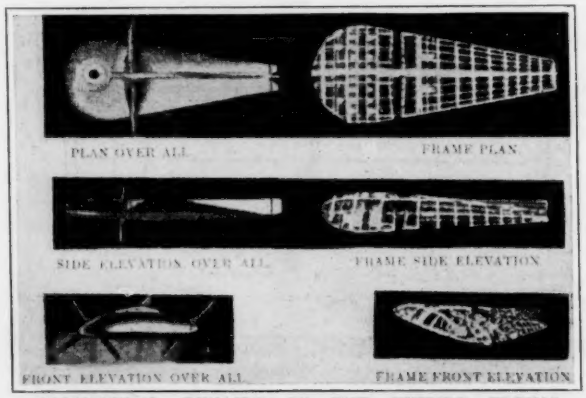
Assume a machine weighing 1,200 tons, flying at 400 miles per hour. It will take 60,000,000 horse-power to provide the air speed necessary to supply a 300-foot diameter wind tunnel! The fact requires analyzing however. The "landing," in other words the reduction of travel relative to earth, will probably take no more than half a minute, probably not more than a quarter of a minute. Say a minute. The horse-power involved, therefore, is 60,000,000 for one minute, and that is equivalent to a 60,000 h.p. plant working for 16 hours.

The figures are high, but the cost of flight must always be high, and there are no half-way measures. Naturally the speeds talked about—1,000 m.p.h.—are high, and there must be no thought of landing except at fixed and definite wind-tunnel-provided stations.

The future flying machine will be in the nature of a humanly guided shell—a projectile. Take the shell of present-day practice, flatten it somewhat in plan form for plane area, streamline its rear end, provide a motor and propellers, and you get the future flying machine. It becomes a projectile, launched and landed, and any intermediate landings are automatically ruled out. Such a projectile will have propellers of huge diameter, judged by present ideas (a 1,200-ton machine will have two propellers of 150 feet diameter running at 100 r.p.m.), and these projecting "sticks" alone will eliminate any possible landing gear. The high speed machine's movement of forward travel must be reduced to zero before its translation from air to earth can be contemplated. A wind tunnel, with a traveling lift to take the weight of machine when stationary, would seem essential. The expense must be high, and £100 a ton-mile may be the cost of flight in 1950. At this rate it will cost 5s. to send a one-ounce letter to Paris from London, but microphotography can reduce its cost to ½d., and the increased speed of transport will amount to an increased speed of 60 to 70 times that of the present means of travel.

A monopoly of inventiveness is not claimed and there may doubtless be other ways of landing the future high speed machines. It is conceivable for example, that it might be practicable to hang on the propellers, and so reduce forward travel to a slow vertical drop. The tail end of machine could then be received into a suitable receptacle and propellers stopped. Needless to say, there would be difficulties in this, but no insuperable objection can be seen.

Naturally, the future machine will be of different type from the present. The loading of any high speed machine must be high, and the speed variation will be very small indeed, quite possibly not exceeding 10 per cent. There will be little enough in common between the present-day and this imaginary future machine. One is a flying machine and the other is a projectile carrying its own motive power. But it is difficult to see how the present machine can greatly advance beyond its present speed except on the lines suggested. As already stated, variable surface is almost impossible; variable camber can help a little only. A much larger speed range is not likely and can never be obtained with high loading. It seems that all effort should be devoted to the problem of landing, and that forced landings between stations must be counted as to be avoided at all costs and classed as serious accidents. The problem is respectfully commended to engineers.



STRUCTURAL DETAILS OF THE FUTURE FLYING MACHINE

*From a correspondent in *Aeronautics* (London).

New Process for the Production of Aircraft Fuels*

Increasing the Yield Over Existing Practice

By Auguste Jean Paris, Jr., and W. Francklyn Paris

THE main object for which the following experiments were conducted was the development of a new method of producing high-grade aviation gasoline. Of almost equal importance was the problem of increasing the yield over existing practice, and also of reducing the cost of production.

The experimental plant was established at Charleston, W. Va., and owes its origin to the offer made to the Government during 1917 and accepted by the National Advisory Committee for Aeronautics early in 1918 for the erection of a test laboratory.

The installation consisted of a suitable building and equipment, including a six horse-power "Foos" gas engine, a 2-ton Brunswick ammonia compressor, high-pressure tanks, condensers, separators, pressure gages, etc., which, together with our services, were offered to the Government without remuneration.

PRESENT METHODS.

The universal method of producing gasoline consists of boiling crude oil in a still, similar to the boiling of water in a kettle, the vapor arising from the oil being passed thorugh a condenser, which consists of a series of pipes lying in a trough of moving water, the water playing the part of cooling the oil vapors, and thus condensing them into liquid which is removed to a cleaning outfit where it is treated with sulphuric acid to remove the unsaturated or cracked products. Sulphuric acid has a great affinity for cracked paraffins such as are produced in gasoline distillation.

The temperature at which the first drop of gasoline condenses from the distillation of crude oil differs according to the age of the oil field from which the crude oil has been obtained, and also according to the length of time it has stood uncovered since its pumping from the well. Crude oil from the Pennsylvania or West Virginia fields will start to boil a 80° F. to 100° F.; and the first drop of condensation will be found at about that temperature. This is known as the initial boiling point.

The temperature of the still is then gradually raised until it reaches the temperature at which it is desired to "cut" off the distillate. This is known as the end point or final boiling point. This latter temperature is controlled by the commercial side of the enterprise, *i. e.*, the supply and demand for gasoline. At 302° F. as a final boiling or end point the end of the real volatile products is reached; and they are about to enter the illuminating or burning oil distillates. Most of the commercial gasolines have an end point of 450° F. This is an indication of gasoline containing a large quantity of kerosene. The higher the temperature of the end point the larger quantity of unsaturated hydrocarbons will be found before cleaning.

It is the practice to clean the gasoline and remove the unsaturated hydrocarbons by a sulphuric acid treatment, removing most of the acid, neutralizing the remaining acid held in suspension by the gasoline by the use of an alkali, and washing with water. The acid absorbs the unsaturated hydrocarbons, thereby producing sulphones which in turn are washed with water.

It is our conviction that a gasoline which has not been in touch with an acid will have decided advantages over one which has. It is also our conviction that a gasoline produced without a heat treatment, such as the distillation at present universally practiced at oil refineries, would be free from cracked or unsaturated hydrocarbons, thereby eliminating the necessity for such acid treatment. A series of experiments have lately been conducted with the following results:

EXPERIMENT NO. 1.

Extraction direct from crude oil.

Raw product, West Virginia crude oil ..... 42° Baumé.
Raw product, quantity used in experiment..... 44 gallons.

Gasoline produced:	Gallons.		
No. 1, 69° Baumé	5		
No. 2, 58° Baumé	10		
No. 3, 55° Baumé	5		
	— 20		
Residue, 37° Baumé	24		
	—	44	gallons.
Percent volatile products		45	

No. 1 is high-grade aviation gasoline.

No. 2 is automobile gasoline.

It is our opinion that a mixture of Nos. 1 and 2 would prove to be a satisfactory aviation gasoline.

All these gasolines evaporate clean and without leaving any odor.

EXPERIMENT NO. 2.

Treatment of crude benzine or first cut from West Virginia crude oil.

Raw product, crude benzine..... 62° Baumé.
Quantity used in experiment..... 97 gallons.

Gasoline produced:	Gallons.		
No. 4, 65° Baumé	51		
No. 5, 59° Baumé	36		
	— 87		
No. 6, residue, 53° Baumé.....	**10**		
	—	97	gallons.

No. 4, 65° Baumé, is aviation gasoline.

No. 5, 59° Baumé, is automobile gasoline.

TABLE I.—*Products of experiments.*

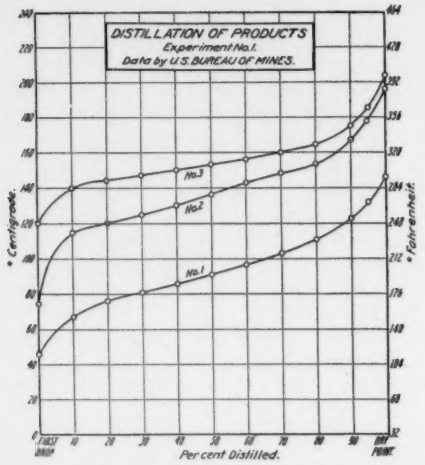
	Experiment No. 1.			Experiment No. 2.		
Product No.....	1	2	3	4	5	6
Specific gravity...	0.704	0.745	0.756	0.7165	0.741	0.7645
Degrees Baumé...	68.9	57.9	55.2	65.4	58.9	53.1
Color.....	W. W.	W. W.	W. W.	W. W.	W. W.	W. W.
Odor.....	O. K.	O. K.	O. K.	O. K.	O. K.	O. K.
Unsaturated.....	1.2%	1.4%	.8%	.5%	.5%	.7%
Doctor test.....	+ or —	+ or —	+ or —	+ or —	+ or —	+ or —
Acidity.....	None.	None.	None.	None.	None.	None.
Loss.....	1.5%	1.0%	1.6%	1.5%	1.0%	.....

DESCRIPTION OF PROCESS USED IN EXPERIMENTS.

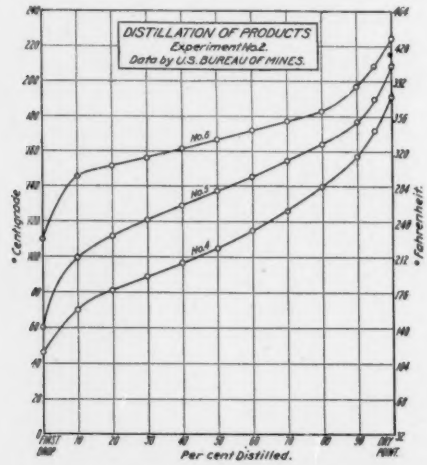
Crude oil or benzine was placed in a closed tank which was supplied with heat from a gas burner sufficient to maintain the temperature at around 200° F. Natural gas at a pressure of about 100 pounds and a temperature approximately 150° F. was allowed to bubble through the oil and thereby absorb the vapors of the lower boiling point hydrocarbons contained in the crude petroleum. This charged gas, at its then reduced pressure of about 10 pounds passed to a single cylinder refrigeration machine and was compressed to about 125 pounds per square inch. During the compression stroke a small quantity of glycerine was sprayed into the cylinder by means of the high gas pressure on the delivery side of the compressor, and mixed with the gas and hydrocarbon vapors therein. The compressed gas, with its then condensed and entrained gasoline, plus the injected glycerine, passed through a settling tank where the most of the glycerine and some of the gasoline were deposited, and then through a water-cooled condenser

*Report No. 42, National Advisory Committee for Aeronautics.

where the most of the remaining gasoline vapors were condensed. A separator was next in line and served to remove the condensed gasoline from the gas which latter was then passed through a reheater where its temperature was raised to around 200° F. by transfer of the heat of the exhaust gases from the gas engine which operated the refrigerating machine. This reheated natural gas then again passed to the tank containing the crude material and so completed the cycle.



During the experiments a small amount of the natural gas was lost by leakage or otherwise and it was necessary to admit more to the system from time to time. The glycerine which was injected into the compressor cylinder served to aid the cold water circulating through the compressor cylinder jackets to abstract the heat of compression and maintain the temperature of the compressed gas and vapors at a low point. The amount of gasoline vapor condensed from the charged gas as the result of the compression was thereby increased. The low temperature of the gas and gasoline vapors also obviated any material cracking or chemical breaking down of the



various hydrocarbons contained. It is also believed that the glycerine was to a certain extent instrumental in removing by absorption some of the impurities contained in the gasoline vapors as received in the compression cylinder.

The experiments were not carried far enough to determine the ultimate possibilities of the glycerine injection process as a means of removing water, sulphur, sulphur compounds, and other impurities from the gasoline. The apparatus used was assembled from material readily available on the market, so that the results do not represent the economic value of this distillation process.

A complete description of the several modifications of the fundamental process described in the above note is contained in patent specification No. 193624, filed September 28, 1917, and entitled "Process of cleaning and refining distillates of petroleum."

THE ABSORPTION OF MINERAL SALTS BY THE TIPS OF ROOTS.

RECENTLY we described in the SCIENTIFIC AMERICAN SUPPLEMENT the remarkable experiments made by M. Henri Coupin proving that plants absorb water by the tip of the root only, contrary to the general supposition. M. Coupin has been contniuing his experiments, of which a report has just come to hand in the Minutes of the French Academy of Sciences. His special object in these later experiments was to discover whether the root tip absorbs not only water but, as seemed highly probable, also the mineral salts dissolved therein, and to find out whether this endosmosis is sufficient to permit the nutrition of the plants. His experiments were conducted in the same manner as before, *i. e.*, the germinations were continued for several days in an atmosphere which was both aerated and humid, and the point of the root *alone* was immersed in the liquid. No matter what kind of plant was under observation this liquid consisted either of Knop's liquid (A) or of redistilled water (B). Knop's liquid is the well known and classic liquid employed in studying the mineral nutrition of plants. It contains 1 gr. of calcium nitrate, 0.25 gr. of potassium nitrate, 0.25 gr. of acid phosphate of potassium, 0.25 gr. of magnesium sulphate and traces of the phosphate of iron. It is necessary to redistil commercial distilled water, since it contains copper, which is apt to be injurious to the roots, and which is particularly likely to kill the vegetative plants. This water must be redistilled in glass. The experiments were carried on in the laboratory, whose temperature was about 20° C. in front of a window which looked towards the north and was admirably lighted. Once every twenty-four hours the germinating seeds were raised so that only the point of the root remained immersed in the water.

"The results obtained with a very large number of species being *strictly identical* three examples will suffice," says Mr. Coupin, "to prove my point. The radicles in question were placed exclusively in the humid air and not in the liquid of the culture. The three plants chosen were peas, the castor oil plant, and white lupine. Careful data were kept and a study of these shows the results to be as follows: Every plant whose root point was immersed in *Knop's liquid* exhibited a distinctly superior development to that of the corresponding plant which was immersed in the *redistilled water*. This difference is manifestly due to the fact that in the first case the nutritive salts had penetrated the root, thus enabling the plant to obtain a better growth than the one which had at its disposal only the reserve substances contained in its cotyledons or its albumen. The conclusion was inevitable, therefore, that *the point of the root is capable of absorbing mineral salts and that the latter are abundantly utilized in the growth of the plant to which they are furnished.*"

SYNTHETIC ASPHALT.

DR. ZIMMER, the director of the Johannes Jeserieh Company, Charlottenburg, has worked out a process which will enable the company in the future to manufacture solid asphalt synthetically, thus rendering it independent of raw material from abroad.

The process has already been patented in nearly every civilized country. A new factory is being erected at Velten, near Berlin, for the utilization of this discovery. The existing building difficulties make it impossible to say when a start will be made with the manufacture of synthetic asphalt. —*Chemiker-Zeitung*, May 15, 1919.

The Diesel Engine and Automobiles*

Developments Necessary to Adapt This Engine to Motor Vehicle Propulsion

By Charles Day, M. Sc.

UP to the present time, the Diesel engine has not been developed along lines suitable for automobile work, for reasons which are stated later, but it does not follow from this that such engines will be confined to their present duties, namely, that of providing motive power for power stations, factories, pumping stations, &c., and for ships.

Quite apart from the possibility of its development for automobile purposes, the Diesel engine forms a very interesting study in the application of theoretical ideas to practical engineering, and the way in which such ideas have very often to be modified to meet practical and commercial conditions. A few moments may therefore be usefully spent in very briefly outlining this point of view.

It is many years since Carnot enunciated the ideal cycle which would give an engine of the highest possible efficiency. Carnot's cycle is illustrated in the diagram, Fig. 1, which can be briefly described as follows:

From A to B the air in the cylinder is compressed isothermally, *i.e.*, without rise of temperature. From B to C (the inner end of the working stroke of the piston) the air is compressed adiabatically, *i.e.*, without transfer of heat to or from the surrounding walls. On the outward stroke of the piston, the heated air expands isothermally from C to D, and then the expansion is continued, but adiabatically, from D to A, the proportion of the various phases being such that the temperature and pressure at the end of expansion are the same as at the commencement of compression.

Accepting Carnot's as the ideal cycle, and trying to apply it in practice, difficulties are clearly apparent. From A to B the compression is to be isothermal. This condition requires that the heat equivalent of the work done in compression be completely conducted away, thus requiring that the cylinder walls be perfect conductors of heat. From B to C the condition is quite changed, as here no heat must pass away; thus it is now required that the cylinder walls be perfect non-conductors of heat. On the expansion stroke the requirements are again similarly reversed.

From this very cursory examination, it would appear that the Carnot cycle is fundamentally impossible of attainment, and so it appeared until Diesel conceived the idea of meeting Carnot's conditions in the following manner:

The cylinder walls must be as nearly as possible perfect non-conductors of heat, thus securing the adiabatic portions of the compression and expansion, while the isothermal compression would be secured by means of a suitably timed fine spray of water injected into the cylinder during the portion A to B, the isothermal expansion being obtained by spraying into the cylinder during the period C to D fuel which would be ignited and burned by the heated air, the fuel being so sprayed as to just maintain the temperature, *i.e.*, to give isothermal expansion.

This proposal attracted great interest, and seemed to open up a realization of the Carnot cycle, and of a perfect heat engine, but unfortunately the ideal has not been attained. It is, however, of interest to note the reasons.

Briefly these were that the necessary working pressures weretoo high, while the mean effective pressures attained were too low.

In Fig. 1 it will be noted that the net effective area is small, and is particularly so in relation to the maximum pressure. Actually the proportions are less favorable than shown in Fig. 1, as this diagram is distorted for greater clearness. Fig. 2 is more nearly representative of the actual pressures.

Perhaps the most interesting, and certainly the most valuable feature of Diesel's proposals, lies in his scheme for spraying fuel into the cylinder, the air in which had previously been sufficiently heated by compression to cause spontaneous ignition of the sprayed-in fuel, as, although other features proposed by Diesel have been abandoned, this feature remains.

The water spray during compression was soon abandoned, thus cutting out the isothermal portion of the compression. In this way the maximum pressure was much reduced owing to the fact that the temperature resulting from adiabatic compression depends upon the ratio of the initial pressure to the terminal pressure. For example, if air is so compressed from a pressure of one atmosphere to a pressure of thirty atmospheres, the resulting temperature is sufficient to ignite most oils, but if at the commencement of the adiabatic compression the air is at five atmospheres' pressure, the compression will require to be carried to thirty times five, or 150 atmospheres, to give the same temperature. From this example, the practical gain resulting from the elimination of the isothermal portion of the compression is evident.

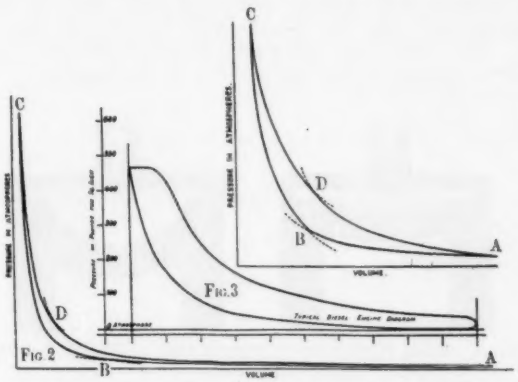


FIG. 1. CARNOT'S CYCLE. FIG. 2. ACTUAL PRESSURES. FIG. 3. NORMAL INDICATOR DIAGRAM FROM A DIESEL ENGINE

The next step was the elimination of the isothermal expansion and the spraying in of the fuel more rapidly. This increased quantity of fuel prevented the pressure from dropping so much during this stage of the expansion, and the general practice is now to introduce the fuel in sufficient quantity to maintain approximately steady pressure during the period of fuel admission. This change is illustrated in Fig. 3, which is a normal indicator diagram from a Diesel engine, and from this it will be readily seen that a very much higher mean effective pressure occurs under the new condition.

With these drastic changes rendered necessary by hard practical facts, the engine differs very materially from the original ideal, but it is of interest to note the phases of development, and it does not appear to be an unfair deduction to say that, as it stands to-day, the Diesel engine works on the nearest practical cycle to Carnot's cycle of maximum efficiency.

The feature which remains, and which is of great value, is, as has already been explained, the spontaneous combustion of sprayed-in fuel.

The Diesel engine as it stands today, differs so far from the original invention, and its development has been due to so many others than the original patentee, that the continuance of his

*From *The Practical Engineer* (London), a paper read before the Institution of Automobile Engineers.

name in association with it is, in the author's opinion, not justified, and it would therefore appear more satisfactory to adopt a technical rather than a personal title. "Spontaneous Ignition Engines" or "High Compression Engines" might meet the case, or alternatively "Spontaneous Combustion Engines." It would not be sufficiently distinctive to speak of them as "Heavy Oil Engines" or "Crude Oil Engines," as other types of engine can use such oils. Whatever title becomes generally adopted, the author is of opinion that it should indicate the fact that the special feature of the engine is the spontaneous ignition of the fuel as distinct from electrical ignition or ignition due to a hot bulb or a hot spot. The name "Diesel Engine," however, being the familiar one at present, it would seem best to retain it for the remainder of this paper.

A type of engine which during recent years has been developed to a considerable extent for small powers is called the "Semi-Diesel" engine. The name, though very widely adopted, is not, in the author's opinion, a well-chosen one, except, perhaps, from a commercial point of view. The broad distinction between semi-Diesel engines and Diesel engines is that a lower compression is adopted for the former, with the result that spontaneous ignition is not possible until the engine is warmed up—consequently, external sources of heat, such as lamps, are depended upon with a semi-Diesel engine until some portion of the combustion space has become considerably heated, after which the external heating can be discontinued.

This question has been dealt with fully in many papers, but the merits of the two systems may be summed up as follows:

Four-stroke Cycle.	*Two-stroke Cycle.*
No scavenging pump.	More uniform turning moment.
Longer time for inlet of air.	Either no inlet valves or no exhaust valves—in some engines neither.
Cooling of pistons and cylinders is easier.	With slow speed engines, weight and space occupied rather less.
Higher mean pressures are attained.	
Lower fuel consumption.	

Turning now to the consideration of the application of the Diesel engine to automobile work, the method of introducing the fuel into the cylinder and the conditions of combustion are at present the limiting factors.

In regard to the spraying of the fuel into the cylinder, it will be readily appreciated that time is a factor in forcing oil through a pulverizer, also that as the viscosity of the oil increases, the time required to force the oil through will increase, unless the pressure behind the oil is increased, or the design of the pulverizer modified. With free flowing petroleum residue oil, and with an air pressure of about 1000 lb. per square inch, the author is of opinion that pulverisers of

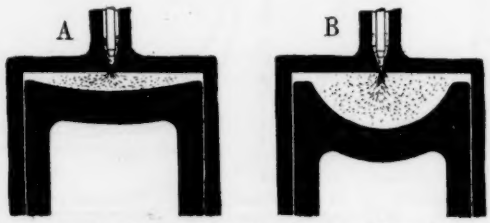


FIG. 4. BEST COMBUSTION SPACE FOR A SHORT STROKE ENGINE

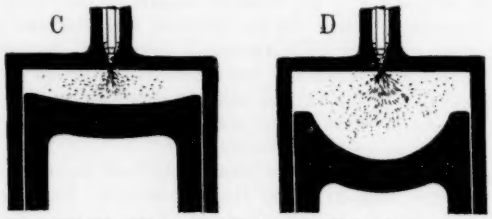


FIG. 5. COMBUSTION SPACE AT LATEST POINT OF FUEL ADMISSION

The system of introducing the fuel in Diesel engines carries with it the following advantages:

(*a*) Pre-ignition cannot occur, as air only is present in the cylinder during compression.

(*b*) No sparking plugs or heated bulbs are used.

(*c*) No carburetors or vaporizers are required, the fuel being sprayed direct into the cylinders.

(*d*) The engines are ready to start at any moment, no previous heating up being required.

Most makers of this class of engine have adopted and still prefer the four-stroke cycle already described, but a great deal of work has been done on the two-stroke cycle, and many quite successful engines have been made on this latter cycle. The fact that in Diesel engines air alone is taken into the cylinder, and not air mixed with gas or with oil spray or vapor, makes this engine particularly suitable for working on the two-stroke cycle. In those engines where the fuel is taken into the cylinder along with the air, there is great risk with the two-stroke cycle of some of this fuel being carried away with the outgoing exhaust which is displaced by the incoming gases. Obviously, this loss of fuel is eliminated if air alone is taken into the cylinder.

Another feature to be kept in mind is that the very short period of the stroke during which the air is taken into the cylinder renders the two-stroke cycle less suitable for high speeds of revolutions than the four-stroke, but, on the other hand, this disadvantage is at a minimum with engines which run at the slow speeds of revolution generally desired for cargo ships. Consequently the two-stroke cycle engine has been developed more for marine propulsion than for purposes where higher speeds are advantageous.

prevailing designs can, with suitable oils, be arranged to deal with speeds up to about 500 or even 600 revolutions per minute. At 600 revoutions per minute the time during which the oil has to be sprayed into the cylinder is approximately 1/200 of a second. For higher speeds pulveriser modifications will need to be developed.

The character of the fuel oil is a factor in the permissible engine speed, both from the point of view of pulverisation and of combustion. Viscous oils are more difficult to pulverize than thin and free flowing oils, and cannot be put through a pulverizer so quickly.

Again, the combustion of heavy and tarry oils is not so rapid as that of refined oils, such as paraffin or petrol, and if the engine speed is so high as not to allow sufficient time for the combustion of the fuel, difficulties will arise from sticky valves, smoky exhaust or dirty cylinders. For rapid combustion a very finely divided spray is of importance, as obviously large drops of oil take a longer time to burn than very small ones.

From this it would seem that high speed engines may need refined oil, in which case one of the great advantages of the Diesel engine will disappear.

The fuel sprayed into the cylinder during a very short period of the stroke, commencing with the piston at approximately the top of the stroke. With a short stroke engine the combustion space into which the oil has to be sprayed is very shallow, as owing to the high compression necessary the clearance volume must be low, say, about 7 per cent. of the total cylinder volume. Remembering the small clearance space, the difficulty of spraying the oil so as to distribute it throughout the air is obvious. Failure thoroughly to mix the oil spray

and air will lessen the possible power of the engine by reducing the quantity of oil which can be burnt.

Improvement in distribution is obtained by dishing the piston top. Fig 4, A, shows diagrammatically the best obtainable combustion space for a short stroke engine, assuming reasonable clearance between the outer edge of the piston top and the cylinder head, while B shows the possible shape of combustion space if the stroke of the piston is doubled.

The combustion space at the latest point of fuel admission is shown in Fig. 5 by C and D respectively. A glance at these diagrams shows how much easier the spraying problem becomes in the long stroke engine than it is in the short stroke engine, especially when it is remembered that it is desirable to avoid spraying or splashing the fuel oil upon the water-cooled cylinder head or on the piston.

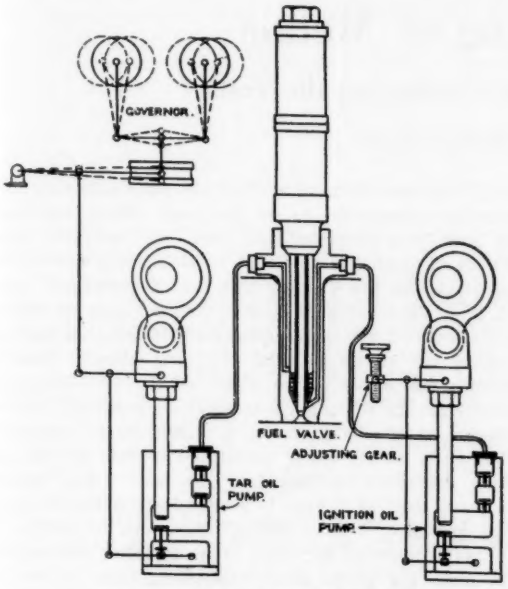


FIG. 6. PILOT IGNITION SYSTEM

In connection with gasoline engines much attention has been given to the production of a turbulent condition of the gases at the time of ignition, but in the author's view such a condition at the commencement of spraying is not so important in a Diesel engine; but, on the other hand, a considerable amount of turbulence should result from the spraying in of the oil so as to ensure the utmost possible mixing of the oil and the air.

Another factor which must be kept in mind for automobile work is range of speed. In the Diesel engine ignition depends upon the temperature of the air at the end of compression, but if the speed of the engine is reduced very much it may happen that the cooling effect on the slowly compressed air is enough to prevent the compression from raising the air temperature sufficiently for ignition. There is thus a limiting factor to the slowness of speed, and the range of speed permissible with the Diesel engine is not so great as with gasoline engines, in which the ignition is obtained by means of a spark.

Before Diesel engines are likely to be applied extensively to automobile work, development along the lines indicated will be necessary, so that higher speeds of rotation can be adopted and reduction of space and weight thus secured.

The difficulties to be overcome before the Diesel engine is suitable for automobile work have been stated, but it is important to make clear that the expression "automobile work" is not intended by the author to cover locomotives, for the Diesel engine as at present developed is applicable to locomotive work, and should find an important fields there, owing to the great economy of working. For outlying districts and for long journeys through sparsely populated areas and countries, locomotives operated by Diesel engines should prove very advantageous, as for such districts electrical operation from fixed power stations is unsuitable.

Compared with the steam locomotive of existing types, the internal combustion locomotive would be cheaper in fuel, and would, if operating electrically, give much higher torque both when starting and when climbing stiff gradients, and it would also use a much smaller quantity of water. Reliability in service and a reasonable cost of upkeep will come with experience. The elimination of stand-by losses and immediate readiness for use are factors of importance in this service.

Fuel Oils.—A very wide range of fuel oils can be used in Diesel engines, as, for instance, petroleum residues, tar oils, some crude tars, shale oils, kerosene, naptha, alcohol or gasoline. Gasoline is only mentioned to illustrate the wide range of fuels permissible, and not as a desirable fuel, for obviously the much cheaper oils would be selected. As already explained, the working of the engine depends upon the spontaneous ignition of the oil when sprayed into the hot air in the combustion space—hence the temperature at which the spontaneous ignition of different oils occurs is a matter of importance. Information on this point being meagre and scattered, Messrs. Mirrlees, Bickerton and Day, Limited, a few years ago carried through in their laboratory a series of investigations on this subject, and from them obtained a lot of useful data, of which the following is an abstract.

Spontaneous Ignition Temperature of Different Oils.

	Spontaneous ignition temperature in oxygen. Degrees C.
Gasoline, No. 1	272
Gasoline, No. 2	270
Kerosene	252
Gas oil	254
Petroleum fuel oil	260
Shale oil (Broxburn)	253
Tar oil	470
Coke oven tar	494
Water gas tar	464
Blast-furnace tar	498
Whale oil	273
Naphthalene	402
Alcohol	395

From these figures it will be noted that the tars and tar oils have much higher spontaneous ignition temperatures than petroleum oils. This means that a degree of compression which will raise the compressed air to a sufficient temperature to ignite petroleum may be insufficient for tar oils—hence engines working on tar oils should have either higher compressions or some other means of raising the temperature of the air. The most widely adopted method is that known as the Pilot ignition system, which is illustrated diagramatically in Fig. 6, a small quantity of petroleum oil is injected into the cylinder in advance of the tar oil, and by its combustion raises the temperature sufficiently to ensure the ignition of the tar oil which follows it. The tar oil is delivered to the fuel valve by the main fuel pump, and enters the space round the fuel valve spindle at a point just above the pulverizer, in the usual manner. A separate pump supplies the ignition oil, and delivers it through another passage in the fuel valve casing to a point just above the inlet to the cylinder. When the fuel valve opens, the ignition oil, being below the tar oil, will enter the cylinder first, and immediately be burned. The combustion of this small charge of ignition oil will, as already stated, raise the temperature in the cylinder to such a degree as to ensure ignition of the tar oil which forms the remainder of the fuel charge.

The use of Diesel engines in power plants ashore, for marine propulsion and for auxiliary power on board ship, has been so fully dealt with in numerous papers that the author does not

propose to deal with these aspects at length; but the Diesel engine is specially applicable in the following circumstances:—

(1) Where power is required at very short notice.

(2) Where the space for power plant is very limited.

(3) Where the load is of short duration, as, for instance, in many electric light stations, as stand-by losses are eliminated.

(4) Where labor is difficult to obtain.

(5) Where the stoppage of a public supply, owing to a strike, would cause great loss or suffering.

(6) Where smoke and pollution of atmosphere must be minimised, and pollution of streams avoided, where chimneys would be unsightly, or where coal dust or ashes are objectionable.

In addition, there are many districts and countries where the relative prices of oil and coal are such as to render the Diesel engine advantageous for almost every purpose.

Even in situations favorable to steam or to gas engines, many occasions will arise in which an engine of the type under consideration can with advantage be installed—for instance, as a spare which can be immediately started up in case of trouble with a boiler or with gas plant.

Some collieries are even now considering the installation of Diesel engines arranged so that pumping operations can be maintained during strikes. The small amount of attention necessary is an important feature of this scheme.

Diesel engines have been successfully used for almost every industrial purpose for which power is required, and their adoption is steadily increasing.

The Impact Testing of Metals*

Types of Machines Designed for Conducting the Tests

By F. C. Thompson, D.Met., B.Sc.

THE introduction of rapidly moving and severely stressed parts in engineering design, especially, perhaps, in motor-car and aeroplane construction, led to a search on the part of engineers for a test in which rapidly applied stresses were involved which should supplement the ordinary tensile test where the rate of loading is relatively slow. The work of Eaton Hodgkinson (1847) and Wöhler (1859) paved the way for the so-called "fatigue" tests in which fracture of the sample is brought about by the rapid repetition of stresses often considerably below the elastic limit as determined in static tension. Many types of such test, which for some time enjoyed considerable popularity, have been devised, but in recent years, and especially during the war, in connection with the inspection of material for air-craft construction, the fashion has changed. The "impact" test, in which fracture of the test-piece is effected by a single sudden blow, has replaced the fatigue test, in some forms of which millions of repetitions of comparatively small stresses were required.

The literature of the subject is now somewhat voluminous, and an interesting bibliography is to be found in a paper by Dr. W. H. Hatfield[1].

The earlier work on impact testing revealed most exasperating discrepancies in the resistance of presumably the same material to sudden and severe stresses. For several years a controversy was carried on between those who claimed that a form of test which yielded such discordant results on samples which, so far as the usual methods of testing were concerned, were identical, was not worthy of credence, and those who saw in it a method so sensitive that variations shown by no other process were revealed. The latter view has been shown beyond doubt to be correct. Especially as a result of the work of Charpy and Cornu-Thenard[2] it has been demonstrated that, given really uniform material, results agreeing within 1 or 2 per cent, can be obtained. It is, therefore, to variations in the steel under test that the apparent discrepancies observed are to be ascribed, this form of test now standing out as probably the most sensitive of all those used in the testing of materials of construction. The impact test has thus at last come into its own, and both as a method of research in determining the best treatment for any given steel, and as a method of routine inspection, has been widely adopted.

It has long been known that the special sensitiveness of this test was not displayed where plain bars of metal were employed; from some form of notched test-piece only was the full information obtainable to be procured. Many varieties of notch have been suggested and used, but the fairly general consensus of opinion is now that a fairly sharp notch is best. When comparing the V notch with the "Copenhagen" type, in which a straight cut ends in a cylindrical hole of relatively large diameter—2 mm.—the superior sensitiveness of the former in picking out brittle material is clearly shown. Since this constitutes the whole *raison d'être* of the test, the marked preference for the sharp notch is obviously justified. Although the radius at the base of the V should be as constant as possible (0.25 mm.), slight variations in this do not make sufficient difference to invalidate the test. The Mesnager notch, much used in France is 2 mm. deep, ending in a semi-circular groove of 1 mm. radius. The work of Philpot[3] has shown that results of the same order as those obtained from impact tests are given by slow bending tests on similarly notched bars, and it would, therefore, appear that it is to the noched test-piece rather than the suddenness of the blow that the remarkable results are to be referred. Since, however, the notched bar test is more rapidly carried out in its impact form, this is the one which finds the chief application. To the subject of the notch repeated reference will be made below.

Concerning the types of machine designed for conducting impact tests, two distinct forms are in use, in which fracture is brought about by single and repeated blows respectively. The latter form of the test, of which the apparatus due to Dr. Stanton is the only one which need be referred to, occupies a position midway between the "fatigue" tests and the impact test proper. The test-piece, ½ inch in diameter and 6½ inches long, is placed on supports 4½ inches apart. A groove, which in the form supplied by the Cambridge Scientific Instrument Co. is 0.05 inch deep and 0.05 inch wide, is made round the centre of the bar, the corners of the notch being practically square. This bar receives blows from a hammer weighing 4.7 lb., the height of fall of which can be varied. The test-piece is rotated through 180° after each blow, about 100 of which are given per minute. The number of blows endured before fracture occurs at the groove is recorded. In the paper by Hatfield to which reference has already been made, results are given which reveal a very close connection between the resistance of steels to the Stanton test and their true elastic limits. Something much more than this is required if the impact test is to justify its existence, with the result that this modification of the test finds but limited application, the

*From *Science Progress.*

[1] *Pros. Inst. Mech. Eng.*, 1919, p. 347.

[2] *Journ. Iron and Steel Inst.*, 1917, II, p. 61.

[3] *Trans. Inst. Ant. Eng.*, April 1918.

single-blow variety being far more commonly employed. The results obtained from these two types of impact tests are often widely discordant, materials which, according to one test, show marked resistance to impact making a poor show when tested by the other.[4]

In all the machines in common use for conducting impact tests a band test is employed. Other types have been suggested, but have found little or no support. Stanton and Bairstow[5] have described and figured an apparatus designed for carrying out impact tensile tests. Four forms of impact bend test are in fairly common use. The two best known of these, the Izod and Charpy types, both employ a falling pendulum to strike the blow. The Frémont machine has a vertically-falling weight, while in the Guillery apparatus a rapidly revolving fly-wheel is used to impact the blow. The essentials of each form are as follows:

In the Izod test the piece, 10 mm. square with a V notch 2 mm. deep at an angle of 45°, is clamped vertically with the height, and at the lowest point of its swing a knife edge which it carries strikes and breaks the test-piece. The residual notch on a level with the face of the die and facing the pendulum. This is released by a spring attachment from a given energy is measured by a pointer which is moved over a graduated scale as the pendulum rises. The height of fall of the centre of mass of the pendulum is 2.5 feet, the striking velocity 13.6 foot-seconds.

The Charpy test differs from the foregoing chiefly in that the test-piece is loosely supported at both ends, the distance between the supports being 40 mm., and that the notch is placed on the opposite side of the test-piece to that on which the blow is received. Although, of course, a notch identical with that used in the Izod test can be and often is used, the specified form consists of a cut 5 mm. deep, terminating in a cylindrical hole 1 1-3 mm. in diameter. The knife edge which comes in contact with the test-piece is here placed vertically in the pendulum; in the Izod machine it is horizontal. In the machine of the usual size the weight of the tup is 22.5 kilograms, the striking energy being 30 kilogram-metres.

In the Frémont test the blow is received from a tup which has fallen vertically through a height of several metres, the striking velocity being higher than in either the Izod or Charpy forms. The test-piece, 8 mm. by 10 mm., rests horizontally on supports 21 mm. apart, with a square notch 1 mm. deep and 1 mm. wide on the longer lower side.

The standardization of the impact test is, as a result of the work of Charpy and Cornu-Thenard, now fairly complete. Despite the differences in the types of apparatus described, the results obtained from similar samples with the same form of notch on all of the machines are practically the same. Not only is the type of machine without influence, but so also is the energy of the blow, provided that this is ample to produce fracture. The work done in breaking the test-piece is, therefore, a definite characteristic of the material.

The results of the test are commonly expressed in terms of the difference in energy of the tup before and after fracturing the test-piece. As Mr. H. Brearley has pointed out, the work done upon the material is expended in the first place in starting the crack at the root of the notch, secondly in extending the crack across the bar, and thirdly in deforming the material in the neighborhood of the crack. In view of this complexity, it is not surprising that no satisfactory general connection has so far been discovered between the dimensions of the bar and the work done in fracturing it in impact. All that it is at present possible to do is to record the work expended in breaking a clearly specified but quite arbitrary type of test-piece.

The unfortunately fairly common practice of expressing these results in such terms as kilogram-metres per square centimetre is most unsatisfactory. The energy used up in breaking, say an Izod test-piece 0.8 sq. cm. in cross-section at the notch, when multiplied by 1.25, does not give the energy required to fracture a test-piece whose dimensions are 1 cm. × 1 cm. at the base of the V. It has been suggested by Mimey[6] that if T_1 and T_2 are the energies absorbed in fracturing two geometrically similar bars of the same material, then $\frac{T_1}{T_2}$ will be proportional to the cube of the homologous dimension, provided that

$$\frac{M_1}{M_2} = \frac{\sqrt{H_1}}{\sqrt{H_2}} = \frac{D_1}{D_2} = \frac{\sqrt[3]{T_1}}{\sqrt[3]{T_2}}$$

where M_1 and M_2 are the masses of the weights, H_1 and H_2 the distance fallen, and D_1 and D_2 the distance apart of the supports for the test-piece. The result is not, however, in agreement with experiments, except where deformation does not proceed as far as the fracture and in the case of untouched bars. For purposes of reducing the results obtained in ordinary impact tests on notched bars, it is useless. In the case of a bar of side χ and notched with a standard groove, the total work done in producing fracture would require a formula of three terms of the form $\alpha\chi + \beta\chi^2 + \gamma\chi^3$. The first term corresponds to the energy expended in starting the crack along the line of the notch, the second to that done in carrying it across the section of the test-piece, and the third to that used up in deforming adjacent material. Since it is often comparatively easy to continue the crack when once it is formed, the importance of the first time—neglected by Charpy and Cornu-Thenard—is evident. The relative part which each of these factors plays will vary considerably in different materials. In, for instance, a hardened steel the resistance to deformation is very great. A crack, therefore, once started extends with ease and without appreciably deforming the surrounding material. A low impact value will thus be recorded. In the case, however, of a metal or alloy with a fairly low yield-point, it may not be possible either to start or to propagate the crack without considerable distortion of the surrounding material. In this distortion considerable energy is used up, with the result that a high impact figure will be given. It is not, therefore, possible to draw any hard-and-fast and say that above such and such a value a material is tough, and below that value brittle. For a steel with a maximum stress of 100 tons per square inch, an impact value of 30 foot-pounds would be extraordinarily good; if the same figure were associated with a tenacity of 60 tons per square inch it would be moderate, while for a 20 or 30 ton steel it would be distinctly poor.

In a crystalline aggregate, as all metallic test-pieces are, both the crystalline portion and the intercrystalline surfaces make their influence felt. As pointed out by Mr. H. Brearley, brittle materials, which, like hardened steel, yield low impact figures, break between the adjacent crystals, which are hardly affected at all. The fractured surface of a brittle test-piece is strikingly crystalline. In the case, however, of a tough sample in which the intercrystalline strength exceeds that of the crystalline portion the reverse of the foregoing conditions obtains. The crack must pass through the crystals themselves; in so doing considerable work is done on the surrounding parts, and a fibrous or silky fracture is shown. The transition of a hardened steel from the brittle to the tough condition on tempering is in part at least due to the softening of the crystalline material, rather than to increased strength of the intercrystalline areas; and in determining at what temperature any given steel should be tempered to yield the toughest product, the impact test gives the highest results when tempering is carried out 50—100° C. below the carbon change-point. To the impact test, therefore, a hard material composed of large crystals is

[4] A considerable amount of information concerning the relationship of the Stanton to other tests will be found in the *Journ. Iron and Steel Inst., Carnegie*, vol. vi, p. 94.

[5] (*Proc. Inst. Mech. Eng.*, 1908, p. 889)

[6] (*Revue d'Artillerie*, July 1911)

typically brittle, a more finely crystalline and softer one tough.

In the case of a forged material, such as steel, the resistance to impast is closely bound up with the direction in which the test-piece itself is cut. A sample cut longitudinally will yield far better results than one cut transversely to the direction of forging. The following results[7] will illustrate this influence:

Angle of Notch with Direction of Rolling.	Work absorbed on Rupture (Kilogram-metres).
0°	1.3
20°	1.5
45°	3.4
90°	13.5

The explanation of these differences lies in the alinement of brittle impurities in the steel as a result of the rolling. Sulphur and phosphorus, present as manganese sulphide and as a solid solution of iron phosphide respectively, are present in long-drawn-out threads elongated in the direction of the forging.

The presence of slag in the steel, which will also be drawn out in the direction of the rolling, deleterious as it is from nearly every point of view, may yet exert a considerable influence in raising the resistance of the material to the impact test, provided that the test-piece be cut in a longitudinal direction. As the crack formed reaches a slag inclusion, which is perpendicular to the direction in which it is growing, a tendency exists for a change of direction, the crack traveling along the line of the slag. Oriented in this way, slag fibres give an increased resistance to impact. If, however, as in a transverse test-piece, the slag lies parallel to the crack, it merely greatly facilitates its passage through the material, very low impact values being obtained. This point is very clearly dealt with by Mr. H. Brearley.[8]

The greatest triumph of the impact test has been the revelation of a new and quite unexpected type of brittleness to which certain alloy steels, especially those containing nickel and chromium were liable. Tempered at temperatures around 600—650° C., and slowly cooled, the resistance of the steel to impact may be almost non-existent, while when rapidly cooled from the tempering temperature, the resistance is excellent. This phenomenon, usually known as "temper-brittleness," is frequently not revealed at all by the tensile test, as the following figures, due to Mr. Brearley (*loc. cit.*), clearly show:

		A	B
Yield-point	*tons per sq. in.*	45.0	45.6
Maximum stress	*Per sq. in.*	53.7	52.4
Elongation	*per cent.*	21.0	21.0
Reduction of area	*per cent.*	55.8	59.3
Impact value	*ft.-lbs.*	2.5	76.5

The two sets of tests were carried out on the same material similarly treated, except that sample A was slowly cooled in the furnace after tempering, B being quenched in water. Although the tensile test is to all intents and purposes unaffected, the resistance to impact of A is only 3 per cent. of that of B. Steels of certain compositions show the brittleness fully; the rate of cooling from the tempering temperature is the essential point; a steel which has become tough or brittle may by appropriate re-treatment be rendered the reverse; no structural change has so far been observed between the brittle and tough states and finally certain casts of steel can never be rendered tough or others brittle. No explanation fully covering the facts has yet been given.

[7] (*Journ. Iron and Steel Inst.*, 1918, ii, p. 24.)

[8] The notch being perpendicular to the test-piece, this sample is cut transversely to the direction of rolling.

Depth Bombs as Guides for Navigation in Fogs*

Destructive Range of Underwater Explosives

By Prof. J. C. McLennan, O.B.E., F.R.S., Scientific Adviser to the British Admiralty

IN the early days of the anti-submarine campaign, a method of destroying submarines whose approximate location was known, was by the employment of depth charges. To use this means it was necessary first of all to know the neighborhood in which it was necessary first of all to know the neighborhood in which the submarine was located, and then the chasing ship would rush to the spot and drop or throw to some distance charges of explosive which detonated when they reached a definite distance below the surface of the water. The necessity of knowing the destructive zone of any given type of depth charge soon became evident, *i. e.*, to determine the radius from the exploding charge, within which a submarine would be successfully destroyed. The same information was important in the laying out and use of minefields. Investigations were undertaken to determine what pressures were generated by charges of different sizes and types at various distances from the place of detonation. The nature of the pressure wave was particularly important, for upon it depends the "killing power" of the charge. The laws which govern the alteration in form and power of waves generated by these explosions had to be determined in order to employ depth charges and mines in the most effectual and economical manner. The accurate determination of the velocity of propagation of the explosive waves generated was also of importance in distributing the charges, for if waves from two different sources arrive at the object in different phases, the effective crushing power may be considerably altered. When we know what the effects of different charges at various distances is—what type of pressure wave, whether a sudden intense blow lasting a few ten-thousandths of a second, or a series of less intense shocks, has the greater effect in destroying the submarine when under water, then we shall know how best to lay out our minefields, and what size and type of charges are the best and most economical to utilize under the various situations which may arise.

A most elaborate investigation of the characteristics of explosion pressure waves has been carried out for the Admiralty by Mr. H. W. Hilliar. By this method the pressure is allowed to act on one end of a steel piston, and measurements are made of the velocity of the piston as it passes a series of points at known distance from its starting point. From these measurements it is only a mathematical operation to extract the acceleration of the piston at different times from the moment when it began to move; in other words, the time history of the pressure acting on the piston. It is not actually feasible to measure the velocity of a single piston at different stages of its travel, but you get the same information if you let the pressure act on a series of pistons and measure their velocity after they have travelled different distances. The velocity is found from the extent of crushing of a copper plug which the piston strikes when it comes to the end of its travel.

As an illustration of results obtained by the method it may be stated that with the measuring gages at a distance of 50 feet from a 300-pound detonating charge of amatol placed

*Abstract from a paper read at the Victory Meeting of the North-East Coast Institution of Engineers and Shipbuilders in Newcastle-on-Tyne.

about 50 feet below the surface, the corresponding time-pressure curve showed that the maximum pressure, 0.80 ton per square inch, was reached almost instantaneously; that the pressure fell to ¼ of its maximum value in 1/1,000 of a second, and practically faded away after 5/1,000 of a second. In the course of the investigation it was shown that the pressure waves are reflected from the water surface as waves of tension. The effect at any given point in the neighborhood of the explosion is, therefore, due to the superposition of a direct pressure wave from the charge and a reflected tension wave from the surface; both travel with the velocity of sound 4,900 feet per second) and the tension wave follows the pressure wave after an interval determined simply by the difference in the length of the direct and reflected paths from the charge to the point in question.

It has been found that the pressure from a large charge is more intensive and more sustained than that from a small one, the two being connected by the following rule. If one charge has twice the linear dimensions of another (8 times the weight) the maximum pressure at a given distance from the larger charge will be the same as at half the distance from the small charge and will be twice as sustained, *i. e.*, will take twice as long in falling to any given fraction of the maximum.

When explosions of gunpowder, for example, were investigated, it was found that the pressure rose much more gradually than when charges of amatol or T.N.T. were used. With this explosion very low maximum pressures were obtained and the corresponding pressure waves were considerably prolonged.

Another method of investigating such pressures, which was suggested by Sir J. J. Thomson and applied by Mr. D. A. Keys, consists in the employment of the phenomenon long known to scientists, namely, that certain crystals become charged with electricity when subject to pressure. The amount of the charge produced is proportional to the pressure applied to the crystals, so by having a suitable arrangement for measuring this charge and its variation with time, a complete record of the variation of pressure with time is obtained by placing the crystal detector at any given distance from the exploding charge. Since the duration of the wave in passing over the crystal or engulfing a submarine is only a few thousands of a second and the pressure generated may be of the order of half a ton or more per square inch, one can readily imagine the difficult nature of the problem in hand. But by making use of the inertia of a beam of cathode ray particles and employing the fact that they carry negative charges and are deflected by electrostatic and magnetic fields, it has been possible to obtain records of the variation of such pressures with the time. The electrons affect a photographic plate, *i. e.*, they leave an impression on the plate where they strike it. This additional fact has made it possible to determine the charge in pressure of the wave from the instant the charge is fired and at as small intervals as we please afterwards. Changes which take place in 1/100,000 of a second have been recorded by this means! Already the method has revealed a number of facts about the nature of the pressure wave produced by exploding charges and the importance of such results in the laying out of minefields and the employment of depth charges can hardly be over-estimated.

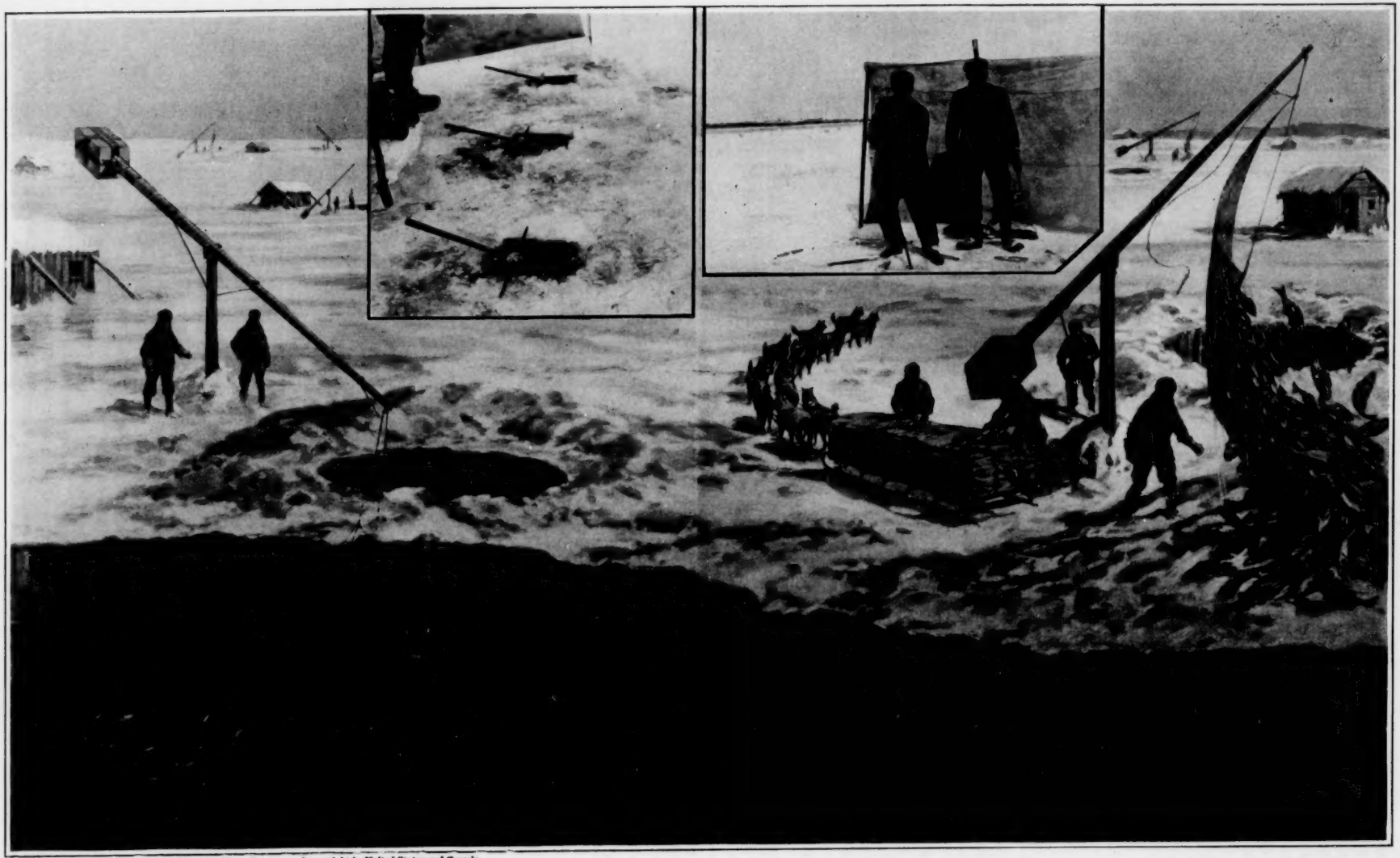
In the course of our investigations of the characteristics of pressure waves generated by the explosion of charges in the sea, it was found that when a hydrophone was used to pick up the waves a good record could be obtained by the explosion of a number 9 detonator at least two miles away. The explosion due to charges of 2 lbs. of T.N.T. have been recorded at 14 miles, and might have been recorded at far greater distances judging from the strength of the signals received. The explosions of 300-pound depth charges have been recorded up to 200 miles, and it is probable that with charges of moderate amount explosions occurring as far away as 500 miles can be readily recorded. Based on these results a system of sound ranging under water was developed. Four hydrophones were laid out 5 miles apart along a base line in deep water a mile or two from the shore and in addition two pilot hydrophones were placed along a line at right angles to the base line, the one 5 miles out and the other at twice that distance. Cables were laid from the hydrophones to a recording instrument situated in a shore station. Four of these stations were installed at different places along the east coast of the British Isles, and other stations are now in progress of installation. With such sound ranging systems the shock of distant explosions occurring under water affect the various hydrophones in turn and as time intervals can be read to 2 or 3 thousandths of a second with the apparatus now in use, it is possible to measure with accuracy the time intervals between the times of arrival of a sound wave at the different hydrophones. With the measurements of these time intervals it is a simple matter to deduce the position of the point at which the explosion setting up the wave is located. Up to 50 miles the location of an explosion under water can be determined to within a few hundred yards by a single station, but for accuracy the coöperation of two stations would be necessary to locate explosions at greater distances. Within operable ranges a ship can be given its position by sound ranging more accurately than by directional wireless or by any other known method. Explosions of mines or torpedoes at any point in the North Sea can easily be located by stations situated in Great Britain. In the war, during the bombardment of the Belgian coast it was a common thing for a monitor to proceed in a fog to a position some miles from the coast and by dropping depth charges have its position accurately determined from stations on the coast of England. So accurately was this done that it was found when the monitor's guns were trained in selected directions objectives several miles inland could be hit with regularity and with a minimum expenditure of ammunition.

SHALE AS FUEL IN ESTHONIA

THE following appeared in the *Esthonian Review*, a weekly published by the Foreign Office of the provisional Esthonian Government, in its issue of October 15, 1919:

We are employing shale in Esthonia now for all manner of purposes; for instance, the Reval gas factory is using it exclusively for producing gas. It cannot yet be burnt as fuel in the fire boxes, at any rate, not as they are constructed at present, because of the large quantity of ash, and the factory, therefore, is using wood as fuel. The quantity of gas obtainable from the shale is greater than from coal. The Reval factory has obtained up to the present 120,000 poods (4,333,500 pounds) of shale. The Port-Kunda cement factory has recently purchased 60,000 poods (2,166,750 pounds) from the Ministry of Trade and Commerce and has a similar amount ordered. It is intended to employ shale mixed with 50 per cent of coal dust in the manufacture of cement.

Experiments in firing locomotives with shale have given very satisfactory results, and the railway factory in Reval is now reconstructing the fire box on one of the engines with the intention of employing shale as fuel. During a recent excursion to the island of Naissaar (Nargo), undertaken by a special commission in order to acquaint themselves with the local conditions, shale was employed exclusively as fuel in place of coal. The experiment turned out quite satisfactorily, a head of steam being obtained equal to that when coal is employed. The difference in cost is remarkable, the price of coal at present being no less than 30 marks a pood and that of shale only 3 marks, so that even if the consumption be more than double, a great saving would be effected. The engineers are of the opinion that when the fire boxes are made suitable for the employment of shale, it will be much cheaper to use this fuel than coal.—*Diplomatic Commissioner Thornwell Haynes*, Helsingfors, Finland, Oct. 18, 1919.



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FISHING THROUGH THE ICE IN THE GREAT LAKES WITH AUTOMATIC BRAILING-NETS

Holes 10 to 12 feet in diameter are cut in the ice and huge automatic dip nets are set. When a sufficiently large catch has entered the net a trigger-pin is jerked loose, a counter weight raises the net and swings it clear of the hole and the net is opened, spilling the fish upon the ice. Fishing with lines is shown in the inserts; at the right hacking a hole in the ice; at the left, indicators which fly up when a fish bites.

Fishing Through the Ice in the Great Lakes*

Automatically Operated Dip Nets

By Winston Fleming

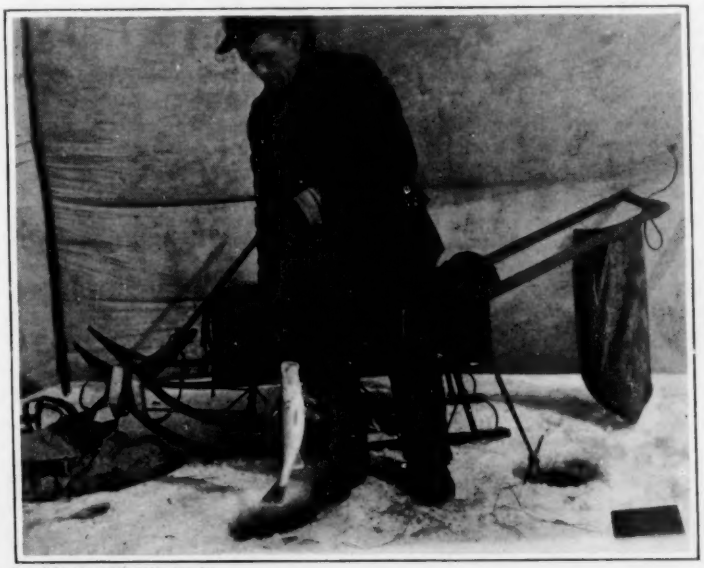
THE Great Lakes of Canada yield millions of pounds of winter-caught or frozen fish every year, a lare part of which is shipped to the United States. The lakes of northern Minnesota and Wisconsin also supply hundreds of thousands of pounds of this food. The total yearly production of this food now approximates 125,000,000 pounds.

Frozen fish in large quantities are shipped to the big cities of the United States every month during the cold weather, where they are sold at less than one-third the price of fresh fish, and still bring a good profit.

The fishing is done through the ice, sometimes miles from the shore, the fishermen living for months at a time in the tents or houses that they have built on their fishing "grounds."

Large holes, perhaps ten or twelve feet across, are cut in the ice and huge dipnets set—nets that will bring out hauls of hundreds of fish at a time. Because of the intense cold the man in charge of the holes must keep going from one to another to prevent the ice from closing his "shaft." At certain intervals a "brailer" makes the rounds and with the net man's assistance pulls up the net and empties the fish on the fresh, crisp snow that is spread on the ice to receive the catch. This snow is necessary to prevent the fish from freezing solid to the ice.

The fish are stacked in great piles, with a blanket of snow between each layer of fish. When the fish are solidly frozen they are loaded in horse or dog sleds and hauled to the nearest shipping point. In the case of the lakes of the Far North this means a haul of several thousand miles—usually by dog team. It is estimated that the fish can be stacked, ready for hauling, in the Great Slave and Bear Lakes at about a half-cent a pound and can be delivered at Edmonton or Calgary at about three and one-half cents a pound—or can be carried on to the States for approximately two cents a pound more. Some idea of the size of this industry is indicated by the fact that in a single day 116 cars of frozen fish went over the main line of the Canadian Pacific Railroad from Edmonton to the States.



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A LONE FISHERMAN MAKING A CATCH WITH A HOOK AND LINE THROUGH THE ICE

The largest fishing operators, however, do not now depend upon hand labor, but have automatic brailing nets instead. These nets automatically swing themselves out of their shafts and empty their catches into the loose snow "dumps," as soon as there are sufficient fish in the mesh to spring the trigger.

Roughly these automatic nets resemble the old-fashioned balance pole at the well, and work on the same principle, except that they are self-operating.

At one end of these balance poles is placed a heavy weight of perhaps two hundred and fifty or three hundred pounds. The other end holds the net. It requires three men to force down the net end and lock the trigger. After that the net is spread in the water and a trigger string run from the pointed iron pin that holds the catch of the pole to the "waist-line" of the net—a small line that completely encircles the net. When a sufficient catch has entered the net to put a strain on this waist-line the trigger string is tightened and the trigger pin jerked loose.

This releases the weighted end of the pole and lifts the net and its fish clear of the water. The pole works on a screw pivot which makes a half turn so that the net, when raised to the full height of the pole, is clear of the "shaft," or fishing hole.

When the weighted portion of the pole reaches its base it springs the trigger that releases the purse line and empties the fish into the snow.

As soon as this is done the net men force down the pole again, adjust the trigger pin and set the purse line—after which the net is ready to resume its automatic fishing operations.

The fish are then loaded on the sleds and hauled to the shipping points.

If they are for local consumption they are forwarded to destination without further preparation, usually being loaded into cars like so much cordwood.

Those that are for shipment to the States for immediate consumption in cold climates are usually bundled up in 100 pound packages and wrapped with sacking.

But those which are to be shipped to the big central markets demand more attention. They are packed in snow-lined boxes of standard size and transported to the big cold storage plants, where they are often kept until the middle of the summer.

As soon as these boxes of fish are received by the cold storage plants they are opened and the contents, which are frozen into one solid piece, dipped in vats of cold running water. The intense cold of the fish freezes the water so applied into a thin coat of ice, which makes them absolutely air tight and less likely to thaw. This is known as "glazing."

Another way of protecting fish packed in this way is to spray the boxes with water right in the freezers, forming an ice coat over the entire pile.

From these central markets the boxes of frozen fish are often loaded into refrigerator cars and shipped to the Southern states, to points where the climate would thaw and decay them were they shipped without protection of any kind.

Usually, however, these fish are kept in storage until the

*Reprinted from the *Illustrated World*.

market is "ready" for them—which means, until they will bring the highest price.

But there are millions of people in this country living in states where the climate will permit frozen fish to be handled like so much cordwood during three or four months a year—at ten cents a pound.

For several years the United States Bureau of Fisheries has been drilling away at the general public, trying to convince them of the fact that frozen fish is a decidedly first-class product, and that it is practically equal to fresh fish in every respect.

Yet fresh fish costs approximately five times as much as the frozen product. This, however, does not prevent ten pounds of fresh fish from going over the counter to every pound of frozen fish.

Last year the cold storage plants of the United States reported a total of approximately ten million pounds of frozen fish in their warehouses; or 1/10 of one pound per capita for our country.

During the winter months one pays about forty cents a pound for fresh fish, whereas in a frozen state this food can be profitably sold for ten cents a pound.

A few years ago frozen fish of the finest quality—bass, pickerel, pike, whitefish, etc.—were sold throughout Minnesota and North Dakota for about five cents a pound. These fish were peddled during the winter months from house to house in open wagons and when purchased could be stored in the woodshed or "leanto" until needed for cooking. In short, they would keep until the cold weather moderated.

Wherever there is cold weather frozen fish can be shipped safely with as little attention as a shipment of sand or stone would receive, or as a car of cordwood—for it is on a cordwood basis that this product is handled.

There are perhaps ten thousand lakes in the northern states that can produce winter-caught fish.

Winter-caught fish were first put on the market in a big way by the fishing interests of the Canadian Great Lakes, of Lakes Manitoba, Winnipeg and Winnipegosis.

As the industry grew hundreds of fishermen flocked to the ice fields of the three big Canadian lakes and pushed on to the waters of the interior to the north. Then a large railway hotel system sent fishing crews out into the wilderness to secure fish for its various hostelries. Soon hundreds of lakes throughout Canada and the Northern States of our country were being "winter-fished."

During the present season it is estimated that the catch will run to over a hundred and fifty million pounds for Canada and the United States.

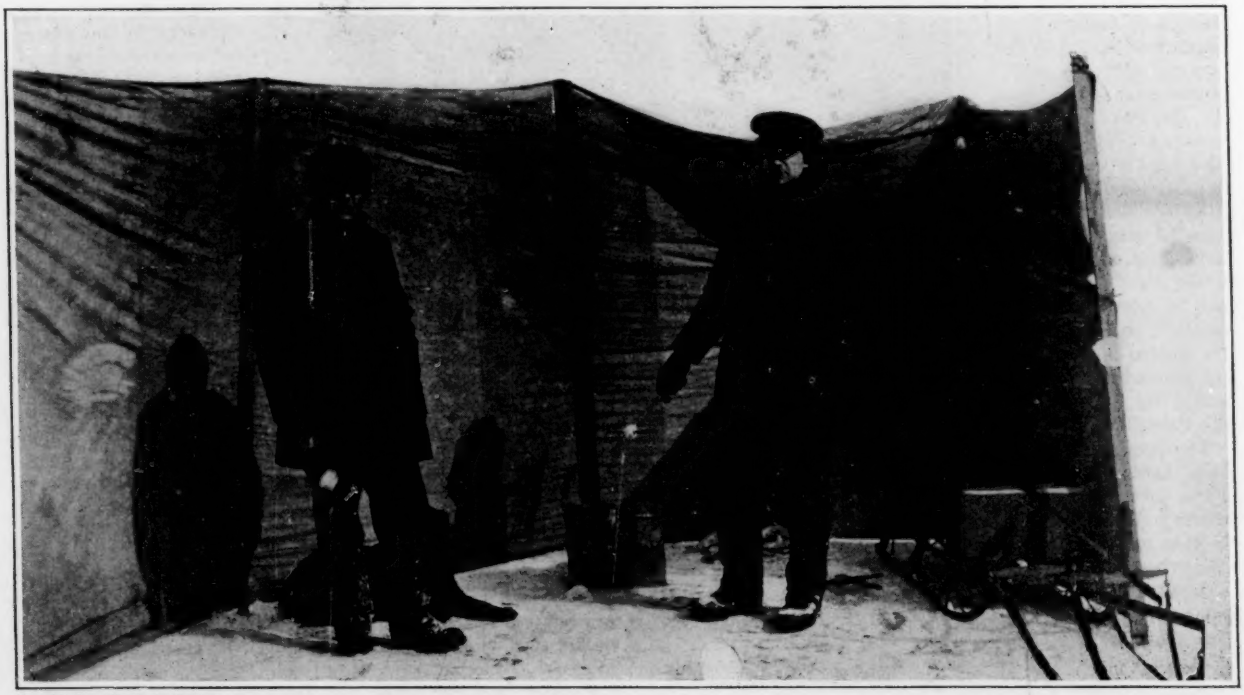
OZONE EXPLOSIVES.

THE war gave a powerful impulse to chemical research in explosive substances and combinations, with the result that several new explosives of great power were adopted to meet new requirements. Some of these will rmain for use in the mining industry and the excavation work of engineering undertakings. The tendency is to get stronger explosives, with a view to lessening manual labor.

Progress seems to lie in the direction of using ozone as the oxidizing agent. In the combination of ozone with one of the aromatic series of substances, as, for example, ethyleozonide, or benzol-tré-ozonide, the so-called ozo-benzol, it releases enormous explosive energy. One kilogram develops an explosion some 2,000 calories, that is, 500 more than nitro-glycerine.

Ozo-benzol not only possesses this enormous energy, but its rate of detonation is exceedingly high, which gives it exceptionally great disruptive power. In this compound endothermic and exothermic reactions unite to bring about its characteristic shattering effects. Oxygen endowed with endothermic energy in the form of ozone combines with hydrogen, under conditions which give the maximum of power, to form the most violently disruptive explosive yet known. With our present knowledge, however, it is rather an indication of the direction in which an advance may be made than a particularly usable explosive.

A. Stettbacher, in a recent address to the members of the Swiss Chemical Society at Zurich, directed attention to another substance, chloric acid, which, like ozone, is of an endothermic and oxidizing nature, and may be used as the active element in an explosive. According to this authority, glycerine tri-chlorate liberates more than 3,000 calories—twice as much as nitro-glycerine.—*Technische Blatt*, June 14, 1919.



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ADJUSTING LINES THROUGH HOLES IN THE ICE. NOTE THE CANVAS WIND SHIELD SET UP TO PROTECT THE FISHERMEN

Power and Speed of Steamers*

Various Resistances That Must Be Overcome

By Arthur R. Liddell

THE experimental tank has done and is doing much towards the solution of the question of the most advantageous forms and proportions of ships in relation to propulsive efficiency. For a given design experimental tests of a rather large number of models bring out relatively favorable conditions. But the process is a protracted and expensive one, and its completion leaves us uncertain whether a still better result could not be attained by further variations in the conditions. The reason of this uncertainty is that the ship's way is opposed, not by one force, but by a number of different resistances which do not always act together. The conditions in a given case may be favorable for the overcoming of one or more of these resistances, but not of the rest. Why the conditions are favorable or otherwise in such cases is not evident on the face of things, and cannot be clearly understood till the different resistances are analyzed separately and estimated as nearly as possible by mathematical means. The reason this analysis is not made is that the large number of unknowns in the problem makes the chances of a successful solution appear too slender. In approaching a task of the kind it is necessary to begin with a number of hypotheses and see where they lead.

The writer of this article obtained from a foreign publication the trial trip particulars of a number of vessels built by a certain firm of shipbuilders. An examination of these particulars led him to adopt certain hypotheses, not all of which will be regarded as orthodox, but which seem to promise tangible results.

The resistances experienced by a ship may be divided into those of:—

(1) Skin friction.

(2) Longitudinal component of excess water pressure on entrance.

(3) Longitudinal component (+ or −) of pressure of echo train—from entrance excess pressure—on run.

(4) Longitudinal component of under-pressure of water on run.

In addition, the propulsive efficiency of the whole installation of ship and motor is further affected by:—

(5) An excess or diminution of pressure of water in way of propeller occasioned by the echoes from the excess entrance pressure.

(6) A like excess or diminution of pressure occasioned by the echo or echoes of the run-wave pressure diminution.

(7) The degree of pressure in the water about the propeller due to the head of water, say, above its center of effort.

With regard to (1) the well-known Froude method of calculation gives results as accurate as can be hoped for at present; (2) has often been dealt with on the assumption that the extra pressure of the water on every vertical frame space of a wedge-shaped entrance is the same, but the results thus obtained have never quite squared with practice. In reality the pressure on any given frame space thus calculated is increased by accumulations of pressure from the frame spaces in front of it, and all these pressures progress sternwards in undulations of gradually diminishing mean intensities. The relative degrees of pressure on successive frame spaces along the entrance can be determined either by mathematical or by graphical means and be set up as ordinates of a curve which starting from zero at the stem, rises in mound-like form to a maximum at half-way length, and when the entrance has the length of a wave, as expressed by knots^2 × .5625, falls to zero again at the after end of the entrance. When the entrance is shorter than a wave length a roughly triangular bit of the after end of the curve is cut off. When the entrance is longer than the wave length the curve falls to zero at the after end of the wave length and then begins to rise again, assuming always that the entrance is truly wedge shaped. The actual entrance is, of course, not so, but the assumption of an equivalent wedge will help towards the solution in principle of the problem. The excess pressure intensities represented by the mound—or mounds—undulate sternwards like the familiar surface waves from the entrance. Each culmination of the undulatory line will be distant from the center of gravity of the original entrance excess pressure mound by a multiple—once, twice, three times, etc., of the length of the wave due to speed. The positions of the entrance wave pressure echoes along the run may be such as to produce excesses or diminutions of the ship's resistance, which, however, are less considerable in amount than was at one time believed. An allowance can be made for them.

Less readily accepted than the foregoing propositions will be that concerning the effects due to the position of the pressure echoes in relation to the propeller. Evidence of these effects may be seen in the fact that the lengthening of a ship often increases her propulsive efficiency—in fact, enables an increased displacement to be driven at a greater speed than before with the same engines. If we may assume the propulsive efficiency as proportional to degree of pressure in the water that the propeller lays hold of the phenomenon is at once explained. But we are then logically brought to the conclusion that the longitudinal position of the echoes from the under-pressure run-depression in relation to the propeller and the head of water above the center of effort of the propeller exert similar influence. Here we are met by the orthodox people who tell us that Beaufoy himself proved that the resistance of a fishlike body to propulsion through water is independent of its depth below the surface. Unfortunately, Beaufoy's writings are accessible only to the few, and even those few are not cognizant of all the conditions under which his experiments were made. No doubt some of his experiments have been repeated by subsequent investigators, but the resistances of the bodies experimented with would be mainly those due to skin friction, a subject our studies of which have not yet gone deep enough.

Very valuable as the Froude investigations and the system of estimating based on them have proved, they "get there" by short cuts. Every imaginable surface is studded with minute projections—visible with the aid of the microscope. A surface attended with very small friction is that of the fish, which is studded with regularly spaced scales or little hillocks with hollows between. Assuming degrees of pressure due to speed and to head of water respectively to play their part in the resistance, we may expect that at the higher speeds the water at the tops of the hillocks will be subject to higher pressures than that in the hollows, and that at very high speeds the hollows may even be denuded of water altogether. In the first case a small part of the surface would be associated with increased and the rest with decreased frictional resistance. In the second case only the smaller part of the surface would be in question at all. As regards head of water, the case does not seem so clear. It looks as though the area of the effective surface would increase with the head, but it may also be that the velocity of gliding of the water over the surface at the same time decreases sternwards at a quicker rate, so that the mean value of the expression area in square feet × (knots) 1.825 for a given length of surface remains comparatively unaltered.

The subject of surface friction needs much more thorough-

*From *The Engineer* (London).

going investigation than it has hitherto received, and, in view of the great possibilities involved, it is more than surprising that such scant consideration has been given to it. Doubtless minute quantities of oil exuded from the scales play a large part in reducing the resistance of the fish, but we may expect the nature of the ups and downs of the surface to be no less important.

With regard to the propeller, one effect that we might expect from an increase of its depth of immersion would be that cavitation would set in later, because the water would follow the retreating blades the more quickly the greater the pressure under which it stood. The known fact that a better result is given by a propeller working below the level of the keel than by one in the ordinary position is usually explained by the freedom of the water there from disturbance. People who think thus fail to realize that the wake disturbance caused by the passage of a ship must extend considerably below the keel—probably nearly as far as to the sides. In shallow water this below-keel part of the wake is interfered with by the ground. The forward motion of the wake is retarded and the echoes—pressure variations—deflected sternwards affect the propulsive efficiency favorably or the reverse according as zones of increased or of diminished pressure happen to be diverted to the propeller. These effects, of course, vary with the distance down of the surface of the ground. That a ship's deep-water speed is sometimes exceeded and sometimes not attained in shallow water is explicable only on some such hypothesis.

The question of the run pressure wave depression and its echoes is more complicated than that of the entrance pressure wave system. The speed of travelling of the ship past the particles of water in way of the run is retarded by the forward movement of the wake, and a part of it is accelerated again by the action of the propeller. It thus becomes a question what speed in knots must be assumed in the expression $\text{knots}^2 \times .5625$ for the length of the run wave. It seems probable that the length of the resultant wave length, if it may be so called, is about the same as that of the entrance wave, but that it is so cannot be taken for granted without further investigation. The actual results of the speed trials above-mentioned have been found to agree surprisingly well with calculations made on the basis of the assumptions of this article, and the principles enunciated may be earnestly commended to the notice of tank experimenters and others in a better position than the writer to pursue the necessary further studies.

The distance of the center of gravity of the entrance pressure mound from the stem may be taken roughly at one-quarter of the sum of the actual length of entrance and of the wave length due to the speed. Similarly the distance of the center of gravity of the run pressure wave from the fore end of the run may be taken at about one-quarter of the sum of the actual length of the run and of the length of the pressure wave due to the resultant speed of gliding of the water past the run. If we now take the longitudinal position of the center of gravity of the entrance pressure mound as that of the first, or parent, culmination and set off a train of wave echoes sternwards there will be increased or decreased pressure in the water about the propeller more or less pronounced according as the distance from the center of gravity is more nearly a multiple, or more nearly a multiple $+ \frac{1}{2}$, of the wave length due to the speed of the vessel. In connection with the run wave a similar influence is at work. The under pressure about the center of gravity of the run depression changes into increase of pressure, the maximum intensity of which will be at a distance of half a run wave length further astern. In good examples of single-screw ships the propeller will be at more than quarter-wave length abaft the center of gravity of the run depression, where the undulating pressure curve has risen to the upper side of its base line. Side screws that are arranged forward of the single-screw position tend to fall and usually do fall within the zone of decreased pressure of the run wave and as a consequence the loss of propulsive efficiency associated with them results.

Sir William White called attention in his "Manual" to the remarkably small difference in the powers for a given speed needed by a vessel in her light and loaded conditions respectively. The smallness of this difference is largely due to the circumstance that the friction producing surface increases more slowly than the displacement, but the difference is greater than this circumstance will account for. The deeper immersion at the same time increases the head resistance and its subsidiary pressure disturbances by large amounts which cannot by any system of theorizing be got rid of. If we first make fair positive and negative allowances for these influences and then take propulsive efficiency in proportion to depth below water surface of the center of propulsive effort of the propeller, we find the resulting power speed conditions for the two draughts to agree fairly well with each other.

In order to determine the proportions of power required to overcome the different resistances the following assumptions have been made:—The extra pressure on a small flat plate moving forward at a small angle with the line of advance is proportional to the sine and nearly proportional to the tangent of the angle. The longitudinal component of this pressure is nearly proportional to the square of the tangent. For an entrance of wave length and wedge shape the head resistance would be proportional to mid area $\times \tan^2 \times \text{knots}^2$ if the pressures on the successive frame spaces did not tend to accumulate and undulate sternwards as shown above. The tendency of the sternward accumulation may be taken into account by squaring the function of the resistance due to the obliquity so that $\tan^2$ would become $\tan^4$, and multiplying by length of entrance. This would give us $\frac{\text{mid area}^2}{\text{entrance}^3}$ in place of $\tan^2$ for a half-wedge of square section. But the half-wedge may not be square and it may be vertical or horizontal. In order to get a mean value of the tangent for these two propositions we may substitute $\frac{\text{mid area}}{\text{half-girth} \times \text{entrance}}$ for $\frac{\sqrt{\text{mid area}}}{\text{entrance}}$. The final expression for the head resistance then becomes $\frac{(\text{mid area})^3 \times \text{knots}^2}{(\text{half-girth})^4 \times \text{entrance}^3 \times \text{const.}}$, which, if not quite satisfactory, takes rough account of the conditions prevailing.

The expression for the over or under pressure at the propeller due to the echoes from the entrance pressure mound is represented by

$$\frac{(\sqrt{\text{mid area}})^4 \times 2 \times \text{knots}^2}{(\text{half-girth})^2 \times \text{entrance}}$$

$\times$ propeller disk area $\times$ a coefficient depending on the longitudinal position of the propeller along the undulation curve $\div$ a constant. It may be positive or negative according as the undulation curve sinks below or rises above its base line in way of the propeller.

The resistance or assistance of the entrance pressure wave echoes in way of the run may be taken account of by the addition or deduction of a percentage of the outcome of the expression for the entrance resistance. This will depend on the positions of the hills and hollows of the undulation along the run. Its amount is somewhat difficult to estimate, but is seldom very considerable. Until further investigation has thrown more light on the problem the resistance of the run depression has been taken as about the same as that of the entrance mound or at least to bear a certain constant relation to it. The expression for the over or under pressure at the propeller due to echo formation from the run under pressure will be the same in form as that given above for the over or under pressure due to echoes from the entrance mound, but the positive or negative coefficient may be much larger in this case, by reason of the shorter distance from source of pressure to propeller and consequent greater height of the undulations in question. Each successive undulation from a

source of over or under pressure appears to be half as high as the one before it.

The constants tentatively adopted in the calculations are $\frac{1}{1800}$ for the expression for the head resistance and $\frac{1}{1600}$ for the expressions representing the additions or deductions on account of pressure about the propeller set up by echoes from the entrance and the run. The center of effort of the propeller disk has been taken at one-third of its immersed height from the uppermost immersed part of it—from its upper edge when it is entirely immersed. In working, the results of the expressions representing the different sections of the resistance have been multiplied at once by the speed in knots instead of this being left to the final calculation. This, of course, is an optional matter.

TABLE A.

	Functions of powers to overcome the different parts of the resistance.					Constant immersion	Estimated I.H.P.	Actual I.H.P.
	1.	2, 3, and 4.	5.	6.	1 to 6.			
Light draught ..	451 +	26 +	19 −	57 −	401 +	$\frac{27}{9.83}$	1101	1173
Load draught ..	430 +	247 +	6 −	154 −	517 +	$\frac{27}{14.17}$	1055	1034

Table A gives an example of the application of the above system to a ship that was tried on the measured mile course both at light and at load draught.

For the light draught some addition must be made to allow for unfavorable conditions, such as that of incomplete immersion of the screw. For the load draught the conditions are better than the average of those of the trial trips dealt with, and the necessary deduction of 2 per cent does not seem excessive.

The best power speed conditions for a given speed and a given approximate length of ship are those in which the entrance and the run are each equal in length to the wave length due to the speed and in which the absolute length from the stem to the propeller is equal to a multiple of the wave length + ½. We may then draw up a table somewhat like Table B. This table can be expanded to any desired degree.

TABLE C.

Length from stem to propeller in wave lengths (W.L.)	Prismatic coefficient.
2½	.6
3½	.714
4½	.778
5½	.818

The prismatic coefficients corresponding with advantageous lengths of entrance and run are given in Table C.

The ballast draught corresponding with a given length may be obtained approximately from the equation draught $= \sqrt{\text{length}} \times C$, in which the constant C will usually lie between .75 and .9. The load draught may be about one and a half times the ballast draught or $1\frac{1}{4}\sqrt{\text{length}}$. Table D. gives a number of illustrations of these proportions for different sizes of vessel.

TABLE D.

Length. Ft.	Ballast draught. Ft. in.	Load draught. Ft. in.
100	7 6 to 9 0	12 6
225	10 9 to 13 6	18 9
400	15 0 to 18 0	25 0
625	18 9 to 22 6	31 3
900	22 6 to 27 0	37 6

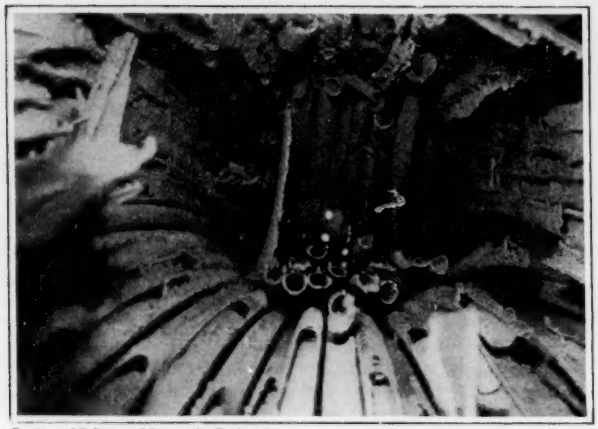
Depth of vessel will be such as to keep the waves from coming over and provide a fairly "dry" ship. In general, the International Rules for Freeboard do this. Breadth of vessel will be such as to give a suitable degree of stability with the conditions of length, depth, and size and extent of erections already determined upon.

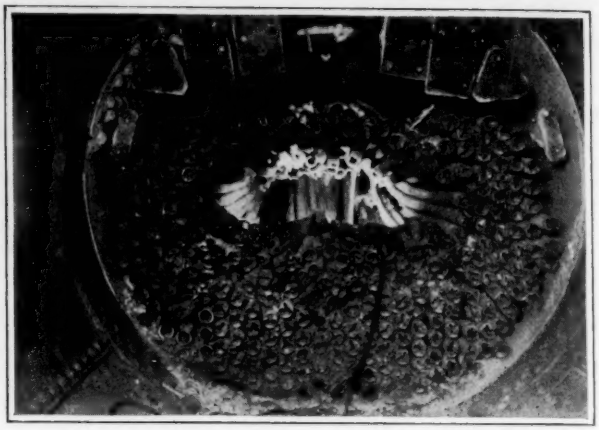
It often happens that other conditions of a given design outweigh those of propulsive efficiency. It may promote economy in other respects to make the length of a ship of given speed greater or less than as given in Table A. If a shorter length is required it will be good practice to lengthen the middle body by extending it so far forward that the longitudinal position of the center of gravity of the entrance pressure mound remains unaltered. Within reasonable limits the difference between the lengths of entrance and run thus arising will probably not be objectionable. For a longer length the middle body would have to be shortened and the entrance lengthened. Increase of breadth of a design will increase resistance in so far that it will make the angles of obliquity of the water lines less acute, but it would be a mistake to try to counteract this effect by a reduction of the prismatic coefficient, because the propulsive efficiency of the vessel would thereby be impaired. The increase of carrying capacity by which the increased resistance due to greater breadth would be accompanied might justify the addition to the horse-power required.

The proportion that breadth should bear to depth depends on conditions other than those of resistance, and its influence on the horse-power needed for a given speed must be taken as it comes. The power speed conditions discussed above are those of cargo vessels and passenger liners of not more than about two and a-half wave lengths in absolute length. Vessels of less than two and a-half wave lengths are beyond the range of the above-named particulars of actual trials, but the effects of wave action may be seen in their performances. Their lengths of entrance and run are each less than that of a wave length due to speed of vessel. The distance from center of gravity of entrance wave to propeller will, with increase of relative speed, soon become less than a wave length. A vessel of one wave length in absolute length will work at a grave disadvantage as regards each of the parts 2 to 6 of the resistance given in Table A. If the vessel be driven at a much higher relative speed—say, at one in which her absolute length is equal to one-quarter of that of the wave length due to her speed—the conditions will in some respects improve. The propeller will then come within the first positive part of the echo from the entrance wave with good results to the propulsive efficiency. The echo from the run wave will carry the under pressure sternward to the propeller and beyond it, with consequent detriment to the propulsive efficiency. At infinitely great relative speed the first echo would carry the entrance pressure almost unchanged to the run and practically balance it, so that the parts 2 and 3 of the resistance would be avoided. The run depression would be carried sternwards unabated beyond the propeller. There would be a certain degree of over-pressure in way of the propeller, making for propulsive efficiency. The squat experienced in a vessel of relatively very high speed is due to difference between the pressure in the water in way of the entrance and that in way of the run. This fact throws light on some experiments carried out with a torpedo boat by Mr. Yarrow. At low speeds the boat went slightly down by the head. As the speed increased this trim changed in succession to those of even keel, slight squat, deep squat, and slight squat growing less with increase of speed.

TABLE B.

Speed in knots.	Length of entrance (= length of run) = wave length (W.L.) in ft.	Advantageous length from stem to propeller.							
		In W.L.	In feet.	In W.L.	In feet.	In W.L.	In feet.	In W.L.	In feet.
10	56.25	2½	140	3½	197	4½	253	5½	310
11	68.06	2½	170	3½	238	4½	306	5½	374
12	81	2½	202	3½	283	4½	364	5½	445
13	95.06	2½	238	3½	333	4½	428	5½	523
14	110.25	2½	276	3½	386	4½	496	5½	606
15	126.56	2½	316	3½	443	4½	570	5½	696





Courtesy of Railway and Locomotive Engineering.

EFFECTS OF SPONTANEOUS COMBUSTION ON THE BOILERS AND FLUES OF A LOCOMOTIVE

A Curious Case of Spontaneous Combustion*

Boiler Tubes of a Locomotive Consumed After the Fire Was Withdrawn

OCCASIONALLY the impossible seems to happen in the mechanical and chemical world and not the least of these impossible paradoxes is the burning of tubes by a seemingly spontaneous combustion, which is reported from time to time.

Here is an illustration of what is meant:

A locomotive was in an accident and was side-swiped. The running board, cab, brackets and main reservoir were torn off from the left side, the guide yoke bent and other minor damages inflicted. Some of the studs holding the running board were also torn out of the boiler, which caused a loss of steam and water. This happened about 12:30 at night. The fire was knocked out of the engine as quickly as possible, the dampers closed and the night roundhouse foreman notified.

At 2 o'clock in the morning the roundhouse foreman went out to the yard and, finding the fire out of the engine, ordered it hauled into the roundhouse. This was done at about 3:30, when it was set in over the cinder pit. Shortly afterwards one of the laborers at the cinder pit came to the foreman and notified him that the headlight had exploded. He went to the engine at once and found the front red hot, which was the cause of the explosion of the headlight. He then took off the small front and found everything red hot inside. The next step was to spark the front end and remove the brick arch, but that did not seem to relieve the heat. To help in the cooling off a plate was put over the top of the stack, and the firebox door opened.

At 6 o'clock in the morning the front end was still very hot, though there was no fire in the firebox or ashpan and the brick arch had been removed. The men were afraid to put water in the front end because of the uncertainty as to what would happen. At noon, or about twelve hours after the accident and ten hours after the fire had been hauled the flues were still red hot in the engine. A part of the tube sheet had been melted as well as the ends of many of the tubes, and the metal had run down into a puddle in the front end.

When the engine was critically examined after it had cooled off, it was found that the greatest destruction was wrought by the heat, just back of the injector check where a large number of tubes were melted.

The illustrations show the condition of the tubes after the removal of the front tube sheet and of the tubes in the interior of the boiler.

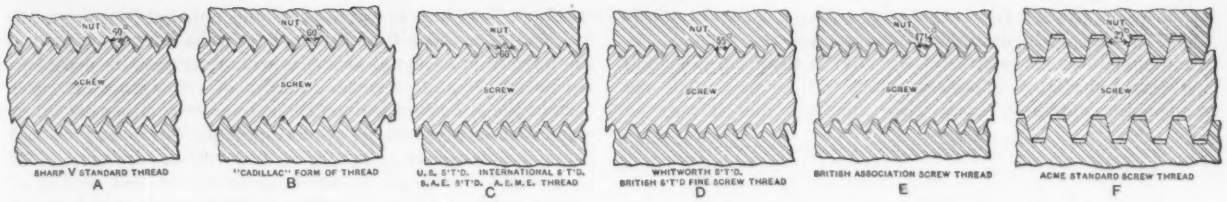
Unfortunately we have no data regarding the exact condition of the tubes in the boiler under consideration, or of those in the pile over the fire, and supposititious case must be built up in order to arive at a possible explanation of the phenomenon before us.

It seems fair to assume that the outside or water side of the tubes was covered with scale, because it is known that the boiler was using a scale-forming water. This insures a certain amount of insulation against radiation of heat from the outer surface of the tubes both by the coating of scale and the quiet air confined in the boiler. It is also assumed that the interior or fire side of the tubes was coated with rust and soot, and that there were some unburned cinders lying in the bottom; though of this there is no direct evidence. It is merely essential to the construction of the case.

Finally we know that there was a brick arch which was hot at the time of the accident and that the ashpan dampers were closed when the heat was developed in the boiler.

Then, with a little air leaking through the dampers, there was a gentle and quite imperceptible movement of hot air through the tubes to the stack, the air having been heated to a high temperature by its contact with the arch. As the water was out of the boiler, and the tubes were fairly well protected against a loss of heat, the air was not appreciably cooled in its passage through the tubes and the latter were heated. *This heated air coming in contact with the iron rust, or oxide of iron, broke it down, and, by so doing, released an excess of oxygen into the air.* This promptly, under the influence of the heat, proceeded to form a new compound with the available carbon, which developed a still further increase of temperature, producing more oxygen, which was immediately available for combustion and which was thus fed without the need of a supply of oxygen from the air. It is merely a simple cycle and quite within the bounds of possibility, and is offered as an explanation of an occurrence that seemed uncanny because it fell outside the range of our ordinary everyday experience. It might have happened from that cause, and the reason it does not happen oftener is that the necessary conditions are not present. There must be an empty boiler so that the tubes and contained air may not be cooled by the surrounding water. The contained air must be nearly stagnant. There must be a source of heat of such a character as not to create a draft and the outer air must be excluded. And there must be present a sufficient quantity of the oxide of iron to supply the needed excess of oxygen, and there must be the carbon to unite with it when it is set free. All these unusual conditions are necessary to the execution of the hypothesis, but when they do exist, there is no reason why the unusual phenomenon here chronicled should not manifest itself.

*Abstracted from *Railway and Locomotive Engineering.*



Courtesy of "Machinery"

FIG. 1. COMPARATIVE FORMS OF VARIOUS STANDARD SCREW THREADS

Standards for Screw Threads

Can a Universal and International System Be Evolved?

By Herbert T. Wade

THE recent war, requiring as it did interchangeability and standardization of military matériel to an extent never before realized, brought distinctly before the civilized nations of the world the importance of international standards. This matter was not settled by the conclusion of the war, but becomes even more important, as a vastly increased international commerce unquestionably will bring to the fore the matter of international commercial standards in many classes of articles and materials. It is inevitable that the markets of the world will be available as never before, and with improved transportation facilities business will come to those that meet the conditions of demand and have their commodities most highly standardized according to some predominant or universal system.

The decision of the United States to avail itself of French and British ordnance and other appliances, as well as manufacture them from their designs, emphasizes the question of standards for various parts, especially screw threads, bolts, nuts, etc., and in the manufacture of vast amounts of equipment by a large number of establishments there was involved securing interchangeability of parts in a marked degree and the use of screw thread systems quite foreign to American mechanical practice.

There was no such thing as a universal or international standard, for in each leading mechanical country of the world, speaking broadly, different standards of screw threads are employed, and in some cases several standards, so that independent of international standards today locally various attempts at standardization have been or are being made. Furthermore the question, while intimately connected with fundamental standards of length, such as those of the Anglo-Saxon and the International Metric Standards, is at the same time quite apart from them, inasmuch as there are different screw thread standards among the countries using each set of measures, and in some cases several standards in the same country. Consequently it would seem that some approach to a single internantional standard is most desirable so that a reasonable degree of interchangeability in tools and parts con be secured, and it is believed that international commerce, and especially commerce in machinery, machine tools and machine hardware would be promoted by such a policy. If there were any single standard to which all countries might conform, the subject would be comparatively simple; but in every country in the last ten years there have been attempts at greater standardization and more perfect standards and systems. Today there are both national and international commissions investigating this matter, so that a consideration of the various systems now in use based on important work done at the U. S. Bureau of Standards is timely and interesting.

So content are people to take for granted reasonably good or at least serviceable systems of standardization in a single country or in a single industry, that often they are apt to neglect the consideration of earlier conditions and at the same time the necessity for still greater improvements. When it is recalled that a freight car can be coupled in any train on any railway in the United States or Canada, and can at the same time be repaired in any shop, it seems difficult to realize that at one time such a condition of affairs was practically non-existent. Today there is the added incentive to standardization that many of the standards used in single nations intrinsically are subject to improvement, and if they are to be improved it is fair to ask that they should also conform at the same time to other and better standards, and should be applicable throughout the entire civilized world. The task that is before engineers, bureaus of standards, physical laboratories, and like institutions, is most apparent, and engineering commissions with varying objects are now working on this subject.

In all of this work the matter of the screw thread is fundamental, as the screw in one form or other enters into practically all machine design, construction and operation. It must be invariable and readily reproduced with high precision by ordinary commercial shop methods of manufacture. On a standard system of screw thread and sizes naturally depend all bolts, nuts, taps, dies, couplings, and the

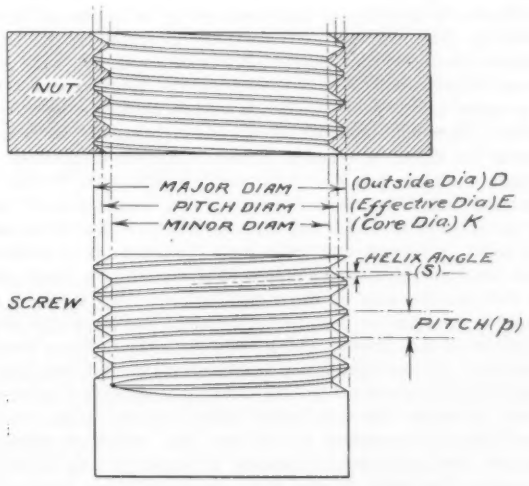


FIG. 2. NUT AND SCREW INDICATING DIAMETERS AS EXPRESSED IN CONVENTIONAL DEFINITIONS

various materials of construction such as pipe which must be purchased in open markets and found within certain limits absolutely interchangeable. In common language they must "fit"; such articles, therefore figure in ordinary

commerce. Now in any consideration of the question of the screw thread, it is desirable to appreciate the various elements and to understand precisely what is involved, including the very important difference in different systems. The accompanying diagrams, show these elements, and it may be

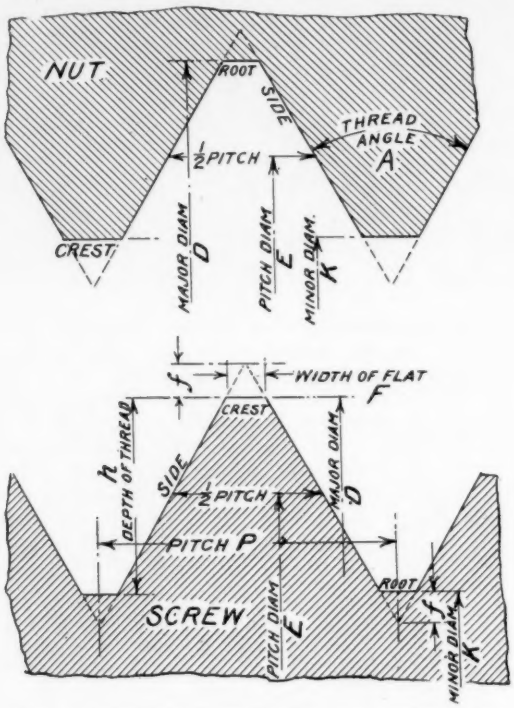


FIG 3. ESSENTIAL ELEMENTS OF SCREW AND NUT WITH CONVENTIONAL TERMINOLOGY AND SYMBOLS

advantageous to reproduce the definitions applicable as recommended by the United States Bureau of Standards. Considering a screw thread, we can define *outside diameter* as the diameter on the outside of the thread, in other words, the external or full diameter. In screw thread formulas as used by the U. S. Bureau of Standards, this is indicated by the letter D. The *root* or *core diameter*, indicated by K, is the smallest diameter, whether for a screw or a nut, while the *pitch diameter*, indicated by E, is defined as the diameter of a screw at a point midway of the depth of the thread equal to the outside diameter, less the depth of one thread, varying in amount for different types of thread. The *top* or *crest* of the thread, or *flat* as it is known in the U. S. Standard Thread, requires no definition, while the *root* is the bottom surface joining the sides of two adjacent threads, whether in screw or nut. The *angle of thread*, expressed by A, is the total or included angle between the sides or slopes of a thread in a plane passing through the axis of the screw or nut. The *slope* of the thread is the angular part which connects the large and small diameters of the thread. The *pitch* (P) is the distance from a given point on one thread to a similar point on the next thread along the axis of the screw, the distance from center to center of two adjacent threads being taken. In a single thread screw this is sometimes called the *lead* which is properly however the longitudinal distance traveled by the screw in one turn. The pitch is also the reciprocal of the number of threads (N) per inch or other linear standard. With these terms understood from the definitions and reference to the diagrams, it is possible to consider the various important screw thread systems now in use and show how they differ and how they might be unified in a single system.

Theoretically in order that screws should be interchangeable both as regards nuts and as regards each other it is necessary that certain of the essential elements named above should be accurate in both screw and nut, but various modifications of a theoretical thread have been made that reduce the number of essential elements where accuracy is necessary for proper fit and interchangeability of screw and nut. For each of the systems described below tolerances either official or more or less accepted in general practice have been worked out and followed to a greater or less extent. In some cases by a slight change as in the diameter of the bolt or nut of certain sizes of screws interchangeability is secured between different systems as the British Whitworth and the U. S. Standard, as illustrated in the accompanying diagram. (Fig. 4.) For various sizes where the pitches are the same the necessary modifications in the effective diameter to secure a satisfactory fit have been calculated.

The British Standard Whitworth Screw Thread was first proposed in 1841 by Sir Joseph Whitworth in a paper read before the Institution of Civil Engineers of Great Britain. The aim of this engineer was to represent so far as thread angle, diameters and pitches were concerned the average engineering practice in England at that time. Sir Joseph Whitworth is quoted as saying: "The mean of the angle in 1-inch screws was found to be about 55°, which was also nearly the mean in screws of different diameters. Hence it is adopted throughout the scale." The profile of the Whitworth thread, which became standard for Great Britain and wherever British machinery was exported, is shown in the accompanying diagram, and in order to make the accepted practice definitely standard, the British Engineering Standards Committee in 1905 adopted the standard Whitworth system, and in a report formulated the dimensions of a system. In this report it is stated: "In the Whitworth form of thread the angle between the slopes measured in the axial planes is 55°, the threads are rounded equally at crests and root to a radius of 0.137329 times the pitch, and therefore the depth of the thread is 0.640327 times the pitch." In other words, one-sixth the height of the basic triangle is cut off from the crest of the thread, and one-sixth the height is filled in at the

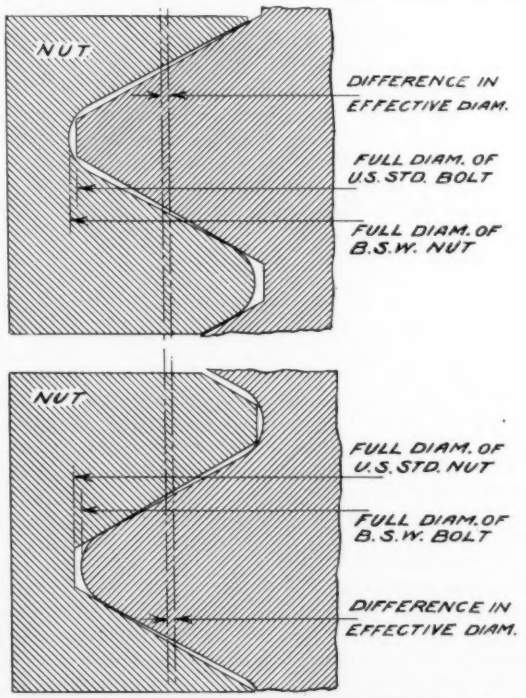

NUT
DIFFERENCE IN EFFECTIVE DIAM.
FULL DIAM. OF U.S. STD. BOLT
FULL DIAM. OF B.S.W. NUT
NUT
FULL DIAM. OF U.S. STD. NUT
FULL DIAM. OF B.S.W. BOLT
DIFFERENCE IN EFFECTIVE DIAM.

FIG. 4. SECURING INTERCHANGEABILITY BETWEEN U. S. STANDARD AND BRITISH STANDARD WHITWORTH THREADS

By slightly modifying the effective diameter of either the U. S. or the Whitworth bolt or nut in pitches common to both systems it is possible to secure interchangeability without modifying the thread form of either.

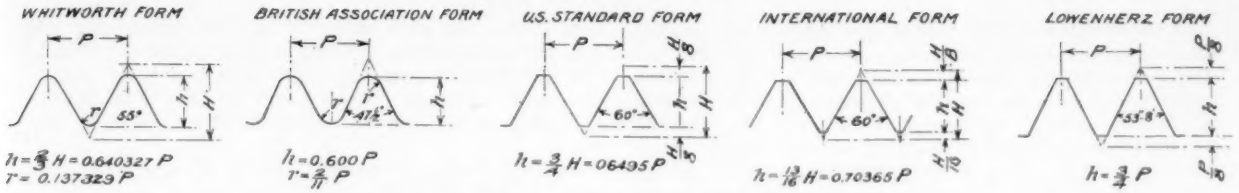


FIG. 5. COMPARISON OF FORMS OF STANDARD THREADS

root. On this system the British Engineering Standards Committee has worked out tables of tolerances for bolts and nuts with considerable elaboration. The Whitworth form of thread is employed for the British standard fine screw thread system, for the British standard pipe thread, and the British standard conduit thread.

The British standard fine screw thread system was recommended in 1905 in order to provide a series of fine pitches to supplement the Whitworth series employing the Whitworth form of thread. The pitches recommended are obtained by the formulas $P = 0.1 \times D^{2/3}$ for sizes up to and including 1 inch diameter, and by formula $P = 0.1 \times D^{1/3}$ for sizes above one inch.

The British standard pipe thread for iron and steel tubes was also adopted in 1905 by the Subcommittee on Screw Threads and linear gages of the British Engineering Standards Commission, and was approved by the main committee in March of that year. Two classes of screw connection were duly recognized by the committee and are now in use, namely, Class 1, the Taper Screw, and Class 2, the Parallel Screw. In Class 1 the screw at the pipe end is tapered 1/16 inch per inch of the length measured on the diameter. The screw in the coupler may be either straight or tapered. Commonly straight coupler and tapered pipe end are used, though conical couplers are used to secure exceptionally good fits. In Class 2 straight screws have the same diameters as the diameters of tapered screws at the gaging notch. The profile of the British Standard Taper Screw for pipe is shown in B of Fig. 8.

The British standard thread for steel conduit is of the Whitworth form, and as for pipes two classes of steel conduit are recognized as standard: Class A, Plain, and Class B, Screwed. In Class A, which is a light gage conduit, neither the ends of the conduit nor the sockets adjoining the lengths are threaded, but in Class B, which is a heavy gage conduit, both of the ends are threaded with the Whitworth form of thread as defined for British standard pipe threads.

Inasmuch as American mechanical engineers employ the same linear standards as the British, it is desirable next to consider the U. S. Standard Screw Threads, which vary from the Whitworth in many important particulars. This thread was also known as the Franklin Institute or Sellers Thread, from the fact that it was proposed by Mr. William Sellers in a paper read before the Franklin Institute in 1864, and duly approved by a committee of the Institute in December of that year. It was adopted with slight modifications by the United States Navy Department and the Master Mechanics and Car Builders' Association, and it is on this standard that the very widespread standardization found in the United States has been carried on, by a formula where $N = \frac{16.64}{(15\,D+10) - 2.909}$ where N equals the number of threads per inch and D the diameter in inches. As a result of this formula values for N are given which agree with the Whitworth pitches, except in two or three sizes.

Now referring to the diagram showing the U. S. Standard Screw Threads, the difference between it and the Whitworth is most apparent in the thread angle, where 60° was selected in place of 55°. Mr. Sellers stated his objections to the 55° angle as follows:

1. The angle of the 55° is difficult of verification.
2. The curve at the top and bottom of the screw will not fit the corresponding curve in the nut.
3. The increased costs and complications of cutting tools required to form this kind of thread in the lathe.

The angle of 60° was selected for two reasons, namely, that it could be reproduced and verified with greater ease, and secondly, because it was also in more general use in the United States. The Sellers system underwent slight modifications, and then became the United States Standard System, where the thread is flattened ⅛ the height of basic triangle at crest of thread and nominally filled in ⅛ the height at the root. The nominal depth of the thread then is 0.64952 times the pitch as is shown in the diagram Fig. 5.

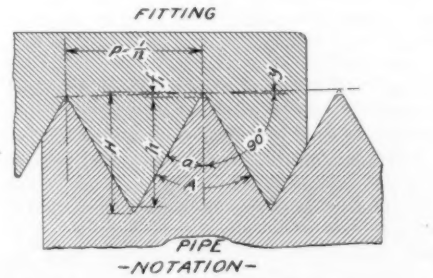

FITTING
PIPE
-NOTATION-
A = 60° Angle of Thread
a = 30° One-half Angle of Thread
y = 1°47' approx Taper Angle = 1/16 per Inch on Diameter
H = 0.866025 p Depth of 60° Sharp 'V' Thread
h = 0.800000 p = 0.923761 H Depth of Thread on Work
f1 = 0.033012 p = 0.038120 H = 0.041266 h Depth of Truncation
p = 1/n Pitch
Number of Threads per Inch

FIG. 6. AMERICAN BRIGGS STANDARD THREAD FORM

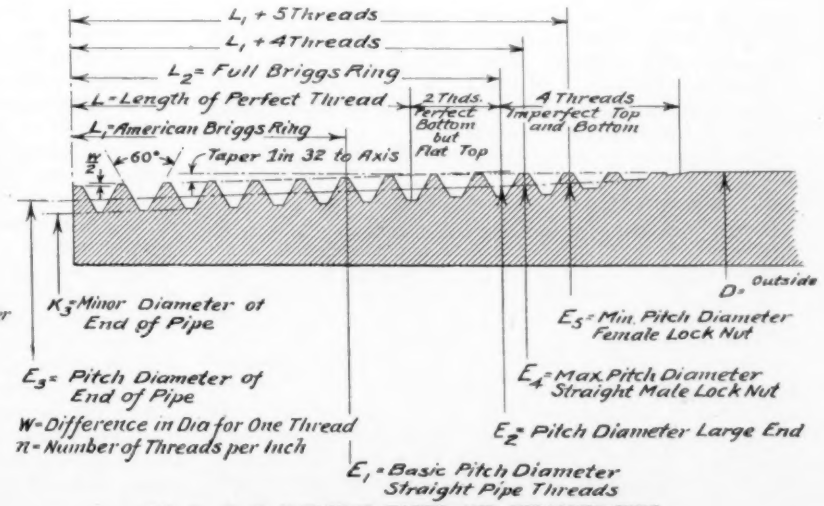

L1 + 5 Threads
L1 + 4 Threads
L2 = Full Briggs Ring
L = Length of Perfect Thread
L1 = American Briggs Ring
2 Thds. Perfect Bottom but Flat Top
4 Threads Imperfect Top and Bottom
60°
Taper 1in 32 to Axis
D = Outside
K3 = Minor Diameter of End of Pipe
E5 = Min. Pitch Diameter Female Lock Nut
E3 = Pitch Diameter of End of Pipe
E4 = Max. Pitch Diameter Straight Male Lock Nut
W = Difference in Dia for One Thread
n = Number of Threads per Inch
E2 = Pitch Diameter Large End
E1 = Basic Pitch Diameter Straight Pipe Threads

FIG. 7. U. S. NATIONAL TAPER AND STRAIGHT PIPE THREAD

In the United States the lack of interchangeability of small machine screws gradually became apparent, and in 1902 the American Society of Mechanical Engineers appointed a committee to report on the standard proportions for these screws. This report was duly formulated in 1907, and the committee recommended the A.S.M.E. Machine Screw Standard where the U. S. Standard form of thread was used and the pitches were a function of the diameter as expressed by the formula

$$\text{threads per inch} = \frac{6.5}{D + 0.02}.$$

With the development of machine work, and especially in the construction of automobiles, it was found that finer pitch screws were required than had figured in the U. S. Standard system, and accordingly the A.L.A.M. Fine Pitch Screw Thread System was developed for automobile work. In 1911 this system was revised and extended. The finer pitch screws were required for automobile work for two reasons: first, fine pitch screws and nuts do not work loose readily when subject to vibration; second, because of increased strength due to increased core diameter obtained, weight could be saved by using smaller screws. Previous objections to using threads of fine pitch that they were easily stripped or crossed in making up did not apply in automobile construction, because it was possible to specify and secure a good fit between nut and screw, and furthermore, it was possible to use a good grade of steel exclusively.

In March, 1918, the Society of Automotive Engineers proposed a system of still finer threads for special automobile work. The automobile industry, on account of the large number of machines manufactured in well equipped and special shops in many cases has employed special screws peculiar to a single manufacturer or organization.

In the United States, while the United States Standard is generally followed, and the 60 degrees angle in the profile, there are various modifications ranging from the sharp V standard, where thread and nut are supposed to fit accurately to special forms used by large manufacturers, examples of which are seen in motor car manufactories. For example, the so-called "Cadillac" form of thread, where the screw thread of the sharp V standard is modified at the crest, it is only necessary to consider the pitch diameter, pitch and angle of thread on the screw and the nut. These two types are shown in profile in A and B of Fig. 1.

The Acme Standard Screw Thread is found in American machine design and takes the place of the square thread, being an adaptation of the form of worm thread commonly employed. It is a little shallower than the worm thread, but the same depth as the square thread, and much stronger than the latter. The Acme thread has a clearance top and bottom, so that the principal consideration involved is the accuracy of the thread as regards the angular faces and its pitch and pitch diameter. The angle of the thread is 29 degrees as is shown in F of Fig. 1.

The width of point of tool for screw or top thread = (0.3707 ÷ No. of threads per inch) — 0.0052.

The width of screw or nut thread = 0.3707 + No. of threads per inch.

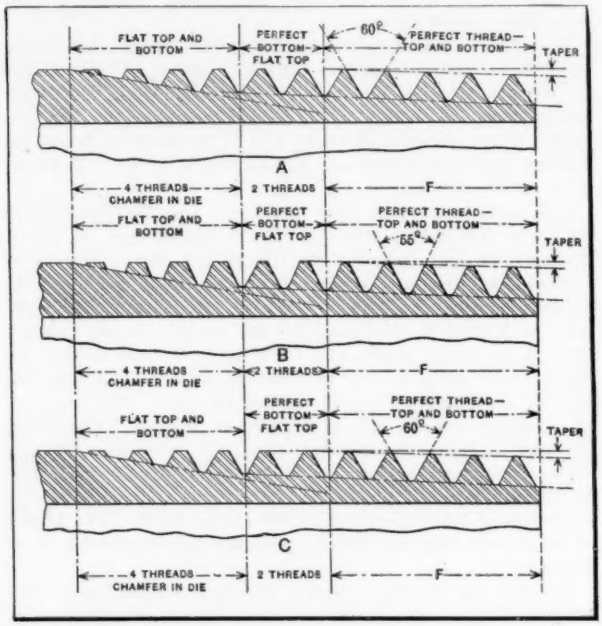
The diameter of Tap = Diameter of Screw + 0.020.

$$\text{Diam. of Tap or Screw at Root} = \text{Diam. of Screw} - \frac{1}{\text{No. of Threads per in.}} + 0.020$$

Depth of thread = $\{1 \div (2 \times \text{No. of Threads per in.})\} + 0.010$.

The Briggs Standard form of pipe thread is in common use in the United States and was adopted by the American Society of Mechanical Engineers, whose committee reported, recommending this system in 1886. The original Briggs Standard pipe thread has an included angle of 60°, and is slightly rounded at the top and bottom, so that the single depth of the thread, instead of being equal to the pitch times 0.866 inch is only 4/5 of the pitch, or equal to the pitch times 0.8 inch. The Briggs Standard is also made in a modified form resembling the U. S. Standard form of thread. The Briggs thread tapers with respect to the axis of 1 part in 32, or ¾ of an inch to the foot total taper. It is very obvious that absolute interchangeability obtained through accuracy of threads and standards is necessary in all mechanical and construction work. Pipe of various forms, together with couplings and other parts, must fit to the required degree of accuracy.

An early attempt to secure precision in screw threads was made in 1878, when the Horological Section of the Geneva Society of Arts recommended a system of screw threads designed by Professor M. Thury. This system was based on the metric standard and reproduced the measurement of well proportioned watch and small instrument screws then in actual use in European countries. The thread has an angle of



Courtesy of "Machinery"

FIG. 8. AMERICAN BRIGGS (A), BRITISH WHITWORTH (B), AND MODIFIED BRIGGS (C) PIPE THREADS

47½°, and is rounded at the crest with a radius of 1/6 p, and at the root with a radius of 1/5 P, giving a depth of thread of 0.6P. The various sizes were designated by consecutive numbers from No. 0 = 6 mm. diameter, 1 mm. pitch, to No. 25, 0.254 mm. diameter, 0.0178 mm. pitch. The pitch corresponding to any size number was expresed by the formula P = 0.^{n}/$_{40}$. The outside diameter corresponding to any pitch was expressed by the formula D = 6 times P ^{6}/$_{5}$. In 1884 the British Association for the Advancement of Science recommended the use of the Thury System with modifications for all screws below ¼ inch in diameter, and this system came into general use, particularly for instruments in scientific work. The modification in the thread form was designed to give equal rounding at crest and root of approximately 2/11 P. The British Engineering Standards Committee in their 1903 report on British Standard Screw Threads gave dimensions of screw threads in this system, including the recommended clearances between the crests and roots of the threads. This system is of interest, inasmuch as it has indicated the practical use in Great Britain of threads based on the Metric System, and no difficulty has been experienced in their use on small apparatus.

With the development of machine tools made according to the Metric System and the general use of the Metric System by the Continental countries, it was obvious that a metric screw thread standard for the larger sizes of screw threads should be adopted. The French Société d'Encouragement de l'Industrie Nationale in 1894 adopted a metric screw thread sys-

tem, and this was approved and adopted by an International Congress convened at Zurich in 1898, and representing the principal Continental countries. The profile of the screw thread is shown in Figures 1 and 5.

In both systems the form of thread had a 60° angle, and the crest of the thread was flattened ⅛ the height of the basic triangle, while the root was filled in 1/16 the height, thus affording a definite clearance between tops and bottoms of threads, and in the main following the profile of the Sellers Thread. The principal difference between the French and the International Systems was in the pitch of the 8, 9, and 12 mm. screws the French specifying 1 mm. and 1.5 mm. pitch respectively, while the International System had 1.25, 1.25 and 1.75 mm. The actual form at the root was left to the manufacturer.

Another important screw thread system used in Continental Europe was originally adopted in 1888 by the Verein Deutscher Ingenieure, and included screws of 6 to 40 mm. diameter inclusive. The thread selected had an angle of 53° 8″, and was flattened at the top and bottom ⅛ the height of the basic triangle, which naturally had a height equal to its base, therefore making a depth of thread ¾ the pitch. In 1893 a commission representing German instrument makers, technical societies and government departments adopted a system of threads ranging in diameter from 1 mm. to 10 mm., and especially intended for use in small machines and instruments. The same form of thread was employed as in the earlier system, and the overlapping sizes from 6 mm. to 10 mm. were identical. This system was called the Loewenherz System, after Dr. Leopold Loewenherz, at one time Director of the Physicalisch-Technischen-Reichs-Anstalt.

It will be apparent, therefore, that irrespective of the fundamental system of linear measures used, whether Anglo-Saxon or Metric, there was and is throughout the world a great diversity of threads, and this was distinctly apparent in the war in the manufacture of ordnance, especially when three countries with different mechanical practice and standards such as Great Britain, France and the United States were concerned in the common manufacture and use of ordnance matériel. In France various systems had been used even within the army, and it was decided during the war to adopt a standard artillery system of screw threads which was based in the main on the International system, modified, however, as was appropriate for ordnance. In the meantime much of the material had been made with various threads, including the Loewenherz Thread, and matériel made in the United States designed to be interchangeable with the French also employed the Loewenherz Thread, for which various gages were sent from France to America.

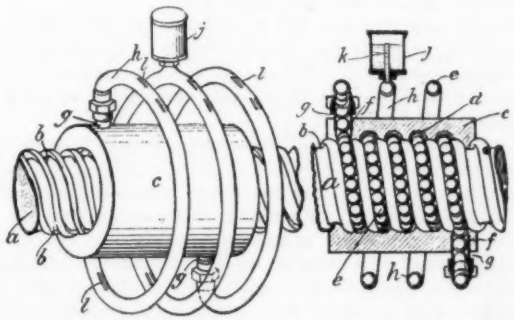
But aside from matters of war material, manufacturers and authorities in the United States and Great Britain, France, and other foreign countries, have been keenly alive to the industrial and commercial situation involved, and during the past year there has been considerable progress made toward international screw thread standardization, though little that is definite or actually accomplished can be recorded now. There have been numerous conferences between American and other national engineering commissions in regard to screw threads and pipe threads. In the opinion of the United States National Screw Thread Commission, which was established by Act of Congress approved July 18, 1918, and continued by a similar Act approved March 3, 1919, to ascertain and establish standards of screw threads for use of the Federal Government and in manufactures, such an international standard should be established by giving consideration to the predominating sizes and standards used in manufactured products, as well as to the possibilities of providing a means for producing this international screw thread by the use of either the English or the Metric System of measurement.

From the foregoing resumé the main points and the divergencies of the various screw threads can be appreciated, and it would not seem difficult to develop a common international system upon which the manufacturing countries could unite at least so far as goods or materials intended for foreign trade are concerned, which system at least could be specified when desired. While important work has been done lately for various national screw thread systems the undertaking will not be complete until one absolutely international standard is secured with proper definition and tolerances, so that with taps, dies, and lead screws arranged on an interchangeable basis all screw products could be reduced to a single system the world over.

ANTI-FRICTION NUT AND SCREW GEARING.*

THE efficient cooling and lubricating of a long run of gearing is often overlooked until certain difficulties arise as to its running efficiency. An improved means of interest has recently been patented by Mr. F. L. Rapson, of Liverpool (patent specification, 131,475). It relates to anti-friction nut and screw gearing and particularly to gearing of the type in which a shaft or rod and a nut or block are formed with co-operating helical grooves for the reception of balls or rollers, which are circulated and returned externally of the block or nut.

As shown, a shaft or rod *a* is formed with an externnal helical semi-circular groove *b* and a nut or sleeve *c*, which is adapted to be slipped on the rod, is formed with a similar internal helical groove *d*. Within these coöperating opposed grooves *b* and *d* is disposed a number of anti-friction rollers or balls *e* to form an anti-friction helical screw thread so



ANTI-FRICTION NUT AND SCREW GEARING

that when, for instance, the shaft *a* is rotated in one direction or the other without longitudinal movement, the block or the like *c* is caused freely to move longitudinally thereon without friction. Adjacent to each end of the block c and at opposite sides thereof is drilled a hole *f*, which extends into the groove *d*. Within each of the pair of holes *f* is inserted or screwed a short tube or pipe *g* of sufficient diameter or size to allow the rollers or balls *e* to pass freely therethrough. These two short tubes *g* of the ball race are connected together by another tube *h*, which is wound spirally around and externally of the block or nut c. This spiral tube *h* is connected to the shorter tubes by unions or other suitable detachable means *i*. Midway between the ends of the spiral tube *h* is provided a lubricator *j*, having a wick *k* which is adapted to wipe the rollers or balls *e* during their movement through the spiral circulating tube *h*. This tube *h* is also provided at the upper side with a number of openings *l* for the admission of air to cool the roller or balls *e* during their circulation through the tube *h*.

In operation, the rollers or balls *e*, which are arranged in close contact in the coöperating grooves *b* and *d* between the stops or pipes *f* and in the spiral communicating pipe *h*, will be carried along the block *c* as the shaft or rod *a* is rotated, and will pass through the pipe *h* and be efficiently cooled and lubricated.

*From *The Practical Engineer* (London).

Unnecessary Fatigue*

America's Multi-Billion Enemy

By Frank B. Gilbreth and Lillian M. Gilbreth, Ph.D.

UNNECESSARY Fatigue is one of the world's greatest of wastes. We believe that a conservative estimate of the loss to our nation in productivity alone is *more than* twenty cents per worker for each and every working day. We have arrived at this estimate after many years of intensive study of this subject, in connection with our work as consulting production engineers in this country and in Europe.

There are *more than* three hundred working days in each year, and the United States census shows *more than* 35,000,000 workers whose outputs are affected by unnecessary fatigue. An instant's figuring shows that unnecessary fatigue, therefore, causes a loss in production that is colossal. This loss is much larger than the *total* fire loss, and the *preventable* fire loss is shocking. This tremendous loss is not for one year alone. It runs year after year. It is continuous.[1]

This astounding loss in production is by no means the total loss which is chargeable to unnecessary fatigue. There is also the loss in materials that are spoiled and in overhead charges caused by the unnecessarily fatigued worker. Again, there is the loss due to absences caused by accident and sickness which are often the indirect result of unnecessary fatigue. Statistics show that the over-tired workers are the ones most often injured and most often absent.

There is also the loss due to the lack of coöperation that comes as a result of the discontent due to over-fatigue, and the resentment due to a belief that the management has not done all it could to provide for the workers' relief from unnecessary fatigue.

These losses are real and tremendous, though to some they may seem intangible.

To those who have not considered the astounding costs to our nation due to unnecessary fatigue, or who do not believe that their own organization is paying heavily for not eliminating such fatigue, we recommend the making of a regular Fatigue Survey of their own conditions. We have found that such a survey will pay in an organization, large or small. It will pay when there are 10,000 employees, and it will also pay in the smallest of organizations, even in one's household. We have found it to pay large dividends in the one, and to help solve the help problem in the other.

Another feature that should be brought out in connection with the problem of eliminating unnecessary fatigue is that all countries are now beset with labor troubles. The cost of living and the amount of wages are traveling upward in an endless spiral, and raises of pay, although large beyond precedent, are not satisfying to the worker because their purchasing power is not simultaneously raised. Too many of our population have not the slightest conception that there is such a thing as an actual science of economics, and many of those who have, have no true conception of its principles. This statement does not refer exclusively to those of little schooling. There are many so-called "highly educated" people who are still clinging strenuously to false conceptions and theories abandoned long ago by practical economists. The day when the majority of the voters will be prepared by education to vote correctly on the great economic questions is in the far distant future. Nevertheless there are certain fundamental principles that could be taught in all schools, even in the primary schools.

For example, it should be realized that *a person's true purchasing power is his producing power*. It should be realized that the greater the production the greater the prosperity. It should be realized that any kind of waste cuts down the producing power, and therefore the earning power.

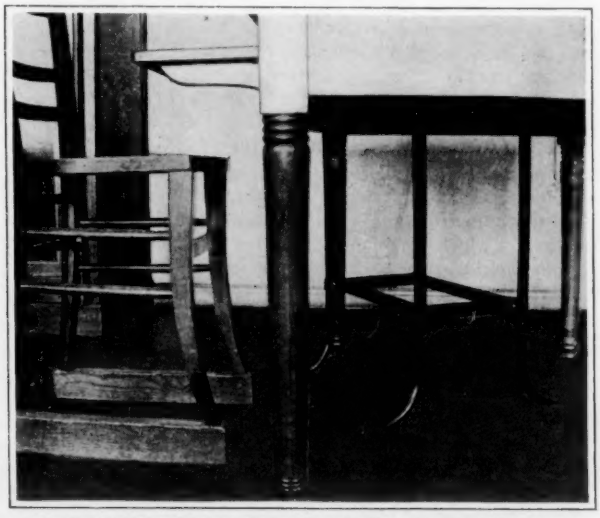
These are most elementary and fundamental principles. It would seem that they are obvious, but on the contrary they are to a large portion of our population by no means obvious. There are hundreds of thousands of people today advocating the reduction of individual outputs as the only cure for all industrial ills.

Now of all wastes and of all hindrances to production, unnecessary fatigue is the most senseless. It does no one any good. Its elimination is a problem in which everyone can share, and all can share also in the benefits derived from this elimination. It is a subject of prime importance because the interests of the employers, the workers, and the public are identical, and therefore coöperation on fatigue elimination will foster better industrial relations.

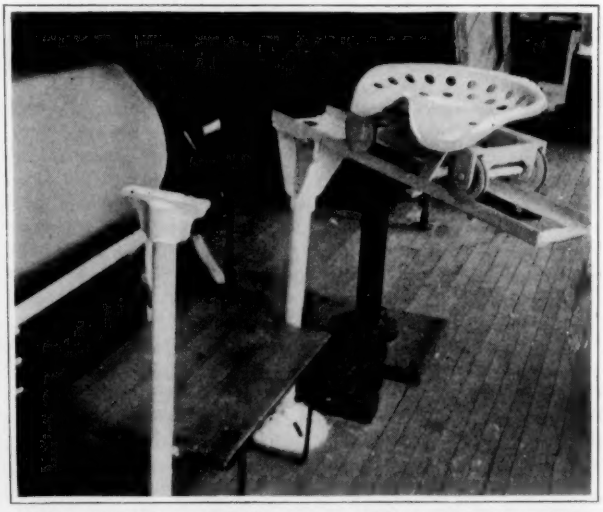
Let us not postpone the beginning of this campaign for

*Delivered before the Society of Industrial Engineers October 29, 1919.

[1]See "Industrial Fatigue in Its Relation to Maximum Output" by Prof. Henry J. Spooner, C.E F.G.S., published by George Routledge and Sons, Ltd., 66 Carter Lane E. C., London.



SIMPLE METHOD OF RAISING A CHAIR TO REQUISITE HEIGHT



LATERALLY MOVABLE CHAIR SWUNG CLEAR OF THE MACHINE

IMPROVEMENT ON THE "STANDING DESK" STOOL

ODD ASSORTMENT OF CHAIRS COLLECTED IN A LARGE AND PROGRESSIVE FACTORY

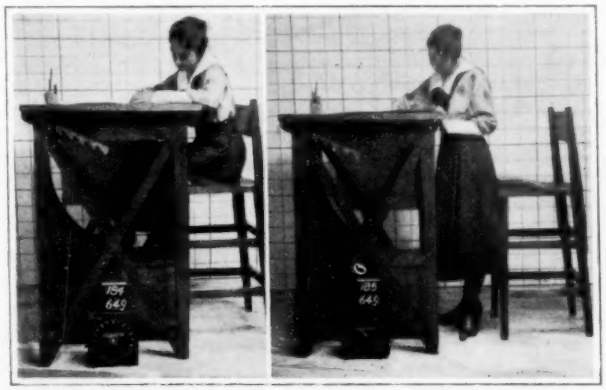
CHAIR WITH ADJUSTABLE BACK AND UNIVERSAL FOOT REST

the elimination of unnecesary fatigue until the division of the profits resulting from it have been determined and agreed upon. The savage Indians knew better than to postpone the accumulation of the spoils until after the arrangement of division was determined. Let the accumulation of the spoils begin at once.

Now how can this campaign be started, and when can it be made? We urge that the first Monday in December each year be recognized as the day on which all organizations take up the subject at meetings of foremen and others, and that the work of other organizations be exchanged and studied. Most satisfactory work has already been done along this line by Professor George Blessing of Swarthmore College.

We have found that the first and logical place to start is with a fatigue survey. The more systematically this is undertaken and the more carefully it is made, the better, but the roughest and most casual survey will instantly reveal oportunities that will more than repay the cost and satisfy any religious yearnings one may have, as an executive or an employer, to comply more nearly with the Golden Rule.

As a matter of fact, the Golden Rule as a method of attack in fatigue study, as well as a law of management has never been excelled. The lack of interest in the past in the fatigue of the workers would justify the old saying, "Man's inhumanity to man makes countless thousands mourn," and inspire a new saying, "Executives' lack of knowledge of the least fatiguing way to make large quantities of production makes countless stockholders kick." This may be the viewpoint necessary to arouse the indifferent manager and add an interested to the disinterested motive.



ALTERNATE SITTING AND STANDING REDUCES FATIGUE

In the fatigue survey perhaps the most important data are those which have to do with lighting, including glare and reflection, and with alternate sitting and standing. There is no excuse today for insufficient lighting or for poorly distributed lighting. Information regarding the good work done by Professors Scott and Clewell and others on efficient lighting is now available, and the shadows and glare from improperly arranged artificial lighting are no longer necessary.

The factory with the machines painted black, the dark dadoes, the "neutral tinted" walls, the piping systems painted distinguishing colors all over instead of at their fittings only, would be ridiculous if they were not so pathetic. All surfaces of all factory workrooms should be painted white. There should be a national law that all enclosed stairways should be painted completely white on the entire ceiling and down to the floor. The whiter the stirway, the more light and the easier for the tired worker to see his way and avoid accidents. More people are killed yearly in the United States by falling down stairs than are killed on the railroads, and the majority of these accidents are avoidable with slight cost and effort. All closets and all lavatories should be painted white.

Walls that are painted a dark color from the floor to a height of from four to six feet can be found in the majority of factories at the present time. This is for the purpose of hiding the dirt. It is the old plan of putting on powder instead of washing the face. The dirt is there just the same, but it is argued, "you can't see it, and it looks nicer." To keep a thing clean, paint it white.

Dirt that shows on the walls and on the machines is seldom of importance compared with the benefits of more light in a factory, and the workers are always more careful when dirt shows. The same thing applies to machines. Our records show that workers keep machines in better condition when they are painted white, and when all dirt is thus made to show. White machines result in less spoilage. The whole tone of workmanship is better when machines are painted white, even when they get daubed with oil and grease.

The present lack of knowledge regarding proper painting often leads to amusing results. We had one client who had painted all interior surfaces of his entire plant the color of pea soup because an artist friend said that that color was "most restful," and in his desire to serve his employees he made the order to paint most emphatic, and the darkest rooms in the cellar were as a result also painted pea green. It is needless to say that they are now being gradually changed to white.

We have carried on some research and studies in our laboratories on finger key-stroke machines, in speed contest work, and in methods of least fatigue, with most interesting results. They illustrate another reason for painting all walls, and surfaces and machines white wherever possible. The depth of focus of the eye is almost exactly proportional inversely to the diameter of the pupil of the eye, and the diameter of the pupil of the eye varies inversely with the lighting. Now the greater the depth of the focus, the less the muscles must adjust the convexity of the lens of the eye. The possibilities of the elimination of the eye fatigue, which means general fatigue is rarely realized, and the simple devices that are now available for measuring actual lighting results are unknown to most executives and workers.

Chairs share with lighting the most important place in the problem of eliminating unnecessary fatigue. Any kind of a chair, steel, box, or rail to sit on is better than nothing. If one must decide between a poor seat and no seat, the poor seat is usually much less fatiguing. Many kinds of work that do not seem to lend themselves to being performed while sitting can be efficiently performed sitting simply by having a chair specially made or altered to suit the individual case. Many kinds of work that appaently cannot be performed while sitting have occasional periods of unavoidable delay during which a worker could utilize that time for resting, if he were provided with a chair available at all times for such periods. Sitting down at least a minute or two each half hour while working makes a big difference in the total fatigue of the day's work as compared with not sitting at all.

Expert salesmen all agree that the seated salesgirl is psychologically handicapped to make the sales and that to sell the average female customer she should be in the attitude and posture of the standing server delighted to serve regardlss of self-comfort. A slogan "Buy of the seated salesgirl" would help this condition.

At almost no cost, factory workers can have their workplaces and chairs designed or altered for their individual measurements, and in the majority of cases should have the table or bench made for working at standing height and a chair arranged to maitnain their elbows the same height above the floor while either sitting or standing. This is not intended to convey the idea of sanction or approval of the too common bookkeeper's chair, with its inhuman round top and its opportunity for the bookkeeper to imitate a woodbine around and through its legs and rungs. That chair was made to satisfy the requirements of a manager of sales of some great furtniture concern who did not care what was done with it after the typical purchaser was convinced that the original price was not high compared with its durability. Most such chairs are too durable. The average chairs of offices and factories are like the traditional definition of a coffin—"The man who made it didn't want it, the man who bought it didn't use it, and the man who used it didn't have much to say about it."

The workers generally have not until recently entered into the fatigue eliminating campaign as heartily as we had hoped and expected. At first we were puzzled, but soon realized that some of the young workers had not so much need of the anti-fatigue devices, and that the strenuousness of youth, of course, set the fashion. The older employees naturally did not care to emphasize their excess fatigue. But when the graphical record shows the difference in production, it puts the matter on a sound footing of economics, as well as comfort and satisfaction, and now we are getting the coöperation and intelligent help from the workers.

Proper eyeglasses will eliminate much unnecessary eye fatigue. Probably no factory can afford to have its workers without the services of a skilled optometrist. The number of workers who need eye glasses or who have improper glasses is much greater than is usually realized. We know of cases in which vigorous workers around forty-five to fifty years old have been tired out, apparently, at quitting time daily and whose earnings dropped off without apparent reason, in some cases as much as 20 per cent, who later exceeded their best records of production after being properly fitted with glasses.

One of the most ridiculous features of our fatigue elimination campaign is the female of the species who becomes thereby convinced of the general principles of the plan, and who becomes most enthusiastic to help in the campaign for the elimination of all unnecessary fatigue, and then comes to work wearing the most pointed toes and the highest of high heeled shoes procurable. This person ranges from the college post-graduate private secretary type to the tuberculous under-paid, under-nourished factory girl from the poverty stricken family.

High heels and pointed toes have their place, a most definite place, and they will probably endure, and their end is not in sight, but that place is *not* in the basket ball court, hand ball court, on the gold links, or the baseball field, *or on the work.* Here is a place in the Fatigue Eliminating Campaign where women at home can help by setting the proper example. High heels and pointed toes worn during the work hours should be made the badge of ignorance or of poverty, or of both. They cause fatigue. They reduce outputs. They decrease national production, when they are worn during working hours. Perhaps they also cause some physical discomfort, but apparently not enough discomfort to offset the satisfaction they give from the consciousness of wearing shoes during working hours that other people wear evenings only. Work should be treated as the greatest of all sports, and working shoes should be selected accordingly.

Life is too short to tell this to women in a plant! It must be made unfashionable by those who set the fashion, and this is no job for production engineers! Women are not, however, the only ones who wear shoes unsuited to their various hours. The photographic records of soldiers' feet permanently deformed by wearing improper shoes prior to enlistment, collected by Colonel W. O. Owen and other officers of the Surgeon General's department are astounding. Mr. Elmer Jared Bliss has done more than any other civilian for correctly fitting shoes to soldiers. It is a fact that over 80 per cent of the soldiers in our army were misfitted before his invention and system were adopted. (See army records.) The one best way to measure and fit shoes has since been micro-motion studied and standardized.

There are some things that we can all do to help. All workers must be taught to arrange their daily work so that it will have less unnecessary fatigue. All workers should be induced to undertake Fatigue study. They should be shown that Fatigue Study is a first step in Motion Study, and usually the most important factor in Motion Study. By studying the phenomena of fatigue, one acquires the habit of thinking in terms of the elements of motions, and as a result increases one's earning power much higher, for the worker who can teach other workers is invariably better paid than one who cannot. Fatigue study will raise one's earning power. It will decrease one's fatigue. It will increase the length of one's productive working life. It will enable one to serve his fellow men. And the possible savings to the nation will be the product of 35,000,000 people working 300 days each year or 10,500,000,000 man-days, times the average amount that the extra productive time and productivity is worth per day. The sum thus arrived at is but the annual payment on Unnecessary Fatigue. The total sum is astounding, especially when it is realized that these great savings are possible with comparatively little effort.

Our country must have greater production in the immediate future. The employers want more profits. Labor wants higher wages. The public must have greater individual purchasing power. This combination can be helped only by eliminating waste. The elimination of unnecessary fatigue offers the greatest opportunity, and the members of this society, under the leadership of its eminent president, will respond to the needs of the people of this nation now, as they did in the world war.

CORN AS FUEL FOR STEAM BOILERS.

WHEN the war cut off Welsh coal from Argentina and a large stock of corn accumulated owing to shortage of railroad transportation the experiment was tried of using corn as a fuel. It was found to have the same calorific value as hard wood or about 2.5 of corn to 1 of best Welsh steam coal. It is usually burned on the cob but if ground to the size of medium sand and blown into the furnace it gives a result in which there is a 2 to 1 comparison with coal.—From *Railway Gazette* (British).

Practical Applications of Selenium—II*

Its Utilization in Biological Chemistry and in the Glass and Rubber Industries

By Louis Ancell

(Continued from Our January Issue)

THE most important applications of selenium lie within the domain of electrical technology and all proceed from the discovery in 1873 by May, a preparer for Willoughby Smith, of the photo-electric property of this substance. This discovery was announced for the first time by Smith in a communication made to Latimer Clark, the President of the English Society of Telegraph Engineers, Feb. 12, 1873. The statement was made that the conductivity of a bar of crystallized selenium augments or diminishes in proportion to the degree of illumination it receives. Werner Siemens was one of the first scientists to utilize this property for constructing selenium cells in 1875. In 1878, Graham Bell, assisted by Summer Tainter, constructed a selenium photophonic receiver which enabled him to hold communications by wireless telephony for a distance of several hundred meters.

The selenium cells prepared by Bell[1] were flat and

FIG. 1. EXTRA-SENSITIVE WOUND SELENIUM CELL

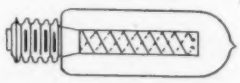


FIG. 2. THE SENSITIVE CELL IN A VACUUM TUBE

consisted of two circular metal plates pierced by holes and separated from each other by a disk of mica. In the holes of one of the plates brass pins were fastened, which penetrated the holes of the other plate, but without touching them. The annular space between the holes and the pins was filled with melted selenium and the whole was then heated over a gas jet, by which means the selenium was transformed into the slatey gray crystalline modification which is sensitive to light.

Bell and Tainter also constructed cylindrical receivers consisting of a pile of disks composed alternately of brass and mica. The mica disks had a smaller diameter than those of brass, so that the annular groove thus left between the two brass disks could be filled with molten selenium. All the metal disks of even rows were connected with one terminal of the apparatus and all the metal disks of odd rows with the other terminal; the molten selenium constituted a semiconducting bridge between the two poles. In the Bell receivers of the flat type the ratio of the sensitive surface to the total surface is equal to 0.11, while in the cylindrical receivers this ratio is considerably greater, being equal to 0.6.

INDUSTRIAL CELLS.

We ourselves have improved this last device in our industrial cells consisting of piles of metal plates separated by very thin insulating sheets. All the plates are bolted together by carefully insulated bolts, the even plates connected with one terminal and the odd plates with the other by means of conductors brazed upon the plates. One of the faces of the pile is very carefully erected and adjusted, the insulators being flush with the edges of the plates so as to present a surface which is exactly plane without having irregularities scattered over it. Upon this thoroughly uniform surface we pour an infinitely thin layer of selenium and transform it by the conditions described above, to the aforesaid violet ray crystalline modification. These pile cells are quite strong, but their sensitiveness is less and their inertia more marked than in our extra-sensitive wound cells.

The latter, like all cells of this kind are constructed as shown in Fig. 1. Upon an insulating support of suitable nature two naked metal wires are wound; copper wires, for example, well insulated and spaced at a very slight interval apart but always parallel. Two of the extremities are free while the other two constitute the poles of the apparatus. If the support is flat one of the surfaces thus coiled is covered with melted selenium which is then brought to the violet-ray crystalline state by a special treatment under a moderate pressure. If the support is cylindrical the entire surface of the cylinder must be seleniated. In our cells the distance between the two wires is 0,04 mm. and is obtained mechanically by the aid of a special coil winder. The diameter of the wire is comparatively small and usually varies between one and five-tenths of a millimeter. We had observed that this distance corresponds to a normal tension of 4 volts or one volt per one 1/100 of a millimeter of the distance between the electrodes, a distance which it is convenient not to exceed, so as to avoid stresses which might cause deterioration of the cell.

The insulating support must answer to the following conditions: It must be strong, non-fusible at a red heat, non-attackable by the melted selenium and the heated metal wire, non-sensitive to variations of temperature and to humidity, and must act as an insulator when hot as well as when cold; finally it must be capable of being fashioned mechanically so as to be brought to the desired form and dimension.

After winding an attempt is made to insulate the cell and if the result is favorable we proceed to sensitize it and then subject it to different tests, including the resistance to the light of a 16-candle power lamp, placed at a distance of 10 centimeters from the cell and in the dark; the measurement of the intensity of the current which traverses the cell under the same conditions when a four-volt accumulator is placed in the circuit; the measurement of the sensitiveness at various distances (Fig. 3) and of the sensitiveness or non-sensitiveness to radiations of various color; and lastly the measurement of the inertia.

The limits of this article do not permit us to give the details of all these tests; we will, therefore, describe only two, which may possess a certain degree of importance from the

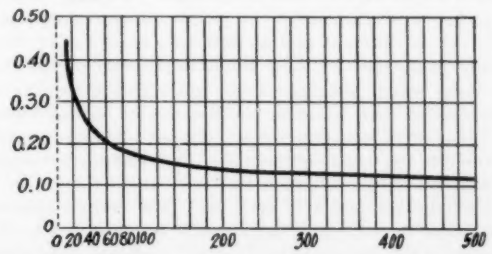


FIG. 3. SENSITIVENESS OF SELENIUM AT VARIOUS DISTANCES FROM A 16-CANDLE POWER LAMP

point of view of applications in industrial chemistry, *i. e.* the measurement of the sensitiveness at different distances and the measurement of the inertia. It should be stated to begin with that these measurements are capable of being made no matter in what mode the cell is constructed.

These measurements may be made, in fact, with cylinders having a seleniated surface; these cylinders (Fig. 2) are

*Translated for the Scientific American Monthly from *Chemie et Industrie* (Paris).

[1]Du Moncel, le Microphone, le Radiophone et la Phonographe, p. 101, Paris, 1882.

generally enclosed in a glass vacuum tube provided with a screw socket like that of an incandescent lamp. Our cells are usually made in the flat form and mounted in a wooden box with or without a cover; the dimensions of the said box vary with the sensitive surface proper, upon which a transparent protecting varnish is spread to prevent air or humidity from producing deterioration of the very thin layer of selenium, whose thickness is, in fact, only one or two 1/100 of a millimeter.

The Measurement of Sensitiveness.—The sensitiveness of a cell illuminated by a source of light having a constant intensity (a candle for example) at increasing distances can be conveniently measured in the following manner: The cell is placed vertically upon a thick support, the height of the flame corresponding to the center of the sensitive surface. A milli-ampere-meter and an accumulator are placed in a circuit connected with the cell. Upon a line perpendicular to the surface of the cell there is then placed a ribbon divided into centimeters; a candle is moved along this ribbon and the distance of the candle from the cell, together with the indication given by the milli-ampere-meter are carefully noted. The curve of sensitiveness is constructed, with the degrees of intensity in milli-amperes in ordinates and the distances in abscissae. The curve obtained shows that the sensitiveness decreases very rapidly at first and afterwards maintains an approximately constant value as the distance increases. This fact is of interest with respect to various applications, particularly in the chemical industry for the control of the draft of factory chimneys (or the stacks of steamboats) and for controlling the rate of progress in a sulphuric acid plant where the catalytic process is employed.

The Measurement of Inertia.—The measurement of the inertia of the cell is of importance for certain industrial or scientific applications, since it is often necessary that the cell should react without delay according to the variation in the illumination which it receives. It is well known that this is not always the case with selenium and an attempt is made either to compensate for this inertia by devices which are sometimes very complex, or preferably to diminish it. It is the latter solution which we have adopted and we have succeeded in obtaining cells whose inertia is negligible from the industrial point of view for the illumination received from luminous sources of a low degree of intensity (from 10 to 100 candle power); this inertia is in general 0.02 per second. The determination of the inertia can be made in the form of curves by the aid of measurements of resistance or, better still, graphically by the following process, invented by us.

For this purpose, the cell under test, is placed at a distance of 10 centimeters from a 16-candle-power incandescent lamp and controls through a 4-volt accumulator one of three styluses of a recording apparatus. These styluses trace records on a drum coated with lamp black. Suppose the right hand stylus is controlled by the cell, then the middle one is vibrated by an electric tuning fork to record hundredths of a second; while the left hand stylus is inserted in the circuit of the lamp which illuminates the cell. This circuit is periodically opened and closed by an electrically operated pendulum. The lamp is momentarily illuminated when the pendulum closes the contact, and is extinguished immediately afterwards. The duration of the illumination, *i. e.* the duration of the contact of the pendulum is 0.15 sec. The cell is influenced by the lamp during this short space of time. The three styluses trace the curves (Fig. 4) which indicate, respectively, at the left, the duration of the illumination between the points A and B in the middle, the hundredth parts of a second, and at the right, the reaction of the cell. Because of the inertia of the various mechanical parts which are in motion, the cell does not react immediately; moreover, this mechanical inertia is constant. The difference between the lengths AB and $A_2 B_1$ expressed in hundredths of a second, gives the inertia of the cell under test. In the case shown in the figures, AB = 0.15 sec. and $A_2 B_1$ = 0/17 sec. Hence the inertia of this cell is 0.02 sec., an amount which is practically negligible from the industrial point of view.

Let us add finally a detail which is of some importance: These extra sensitive cells may be made to last a very long time by taking certain precautions, including the avoidance of shocks, of humidity, and of sudden differences of temperature; thus a cell constructed by us in March, 1912, for the photometry of the eclipse, is at the present moment (March, 1919), quite as good as at the beginning. The measurement of the inertia of selenium cells, can also be made as we have

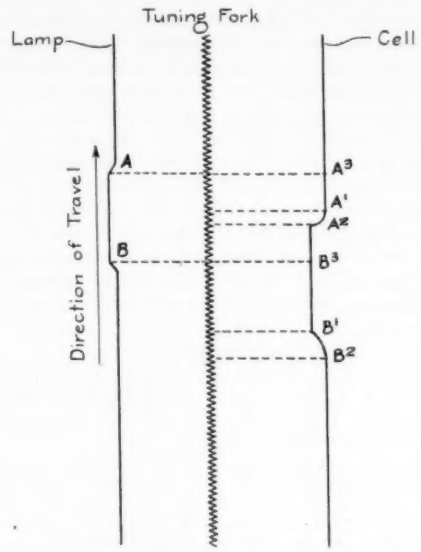


FIG. 4. MEASUREMENT OF THE INERTIA OF A SELENIUM CELL

already proposed[2] by two other distinct processes, somewhat less convenient in character:

1. The graphic process by means of points made by hand.
2. The photographic process, which is entirely automatic, either by employing the device of the oscillograph for the rapid variations, or by the process described for the photometry of the eclipse.

The graphic process consists in measuring under conditions that remain identical the resistance of a cell connected with a 4-volt accumulator and with a sensitive ohm-meter, first in the dark and then in the light of a metal filament incandescent lamp of 110 volts and 16-candle-power placed at a distance of 10 centimeters above the sensitive surface of the cell. Upon a sheet of paper ruled into square millimeters there are laid off in ordinates the resistances expressed in thousands of ohms, and in abscissae the times expressed in minutes.

The resistance of the cell in the dark (after a stay of fifteen minutes at least) is noted and the cell is then illuminated for 60 seconds by opening a shutter placed between the lamp and the cell. We then note rapidly the new value of the resistance and repeat this from minute to minute, the cell being placed again in the dark until its return to the initial value which it possessed in the dark (a period of about 20 minutes). The points thus obtained are then united by a continuous line which gives a curve which descends very rapidly between the first point and the second point and afterwards slowly ascends for the following point. This curve represents the inertia of the cell with respect to a given degree of illumination.

To cipher this inertia we construct the theoretical curve of a supposed cell without inertia, and we integrate, for

[2]Louis Ancel. Avenir de la T.S.F. (Future of Wireless Telegraphy), No. 19, p. 261.

example, by the aid of an Amsler planimeter, the surface comprised between the theoretic curve, the axes of the coördinate and the last ordinate with respect to the last point obtained. We obtain a value B. In the same way we make a new integration of the surface comprised between the real curve obtained by points the axes of coördinates and the last ordinate. We obtain a value A, which is smaller than B. Inertia is smaller than 1 and represents the inertia of the cell. The closer the approach of this ratio to unity the better the cell and the feebler its inertia. If we have no planimeter we operate by weighing the paper. The surface B is first cut out and the scrap of paper is weighed to within approximately a demi-milligram; then the same thing is done for the surface A; the ratio of the two rates thus obtained represent the inertia of the cell. It is necessary to repeat the same operations upon a cell in identical conditions at various times in order to obtain an idea of the variations of the inertia and an indication of the vitality of the cell; in point of fact as soon as $\frac{A}{B}$ perceptibly diminishes the cell gradually deteriorates.

The photographic process may be employed in two different ways according to whether it is desired to measure the inertia of a cell illuminated by a source of light whose intensity progressively decreases and then gradually increases after reaching a minimum point, which point may even have complete obscurity (this is the study of the inertia of the cells employed in the photometry of eclipses by means of the apparatus described above); or again by the measurement of the inertia of a cell illuminated by a source of light which has been rendered vibratory by the aid of a sound, for example, in order to study the behavior of a cell subjected to a series of rapid variations and of a feeble luminous intensity (this is the study of the inertia of the cells employed in the process of wireless telephony by means of luminous waves). In the latter case we make use of an oscillagraph or of an apparatus consisting of a sort of Pollak-Virag photo-telegraph. The oscillograph is too well known to need description here. The Pollak-Virag apparatus consists in sum of a photographic recorder in which the mirrors set in motion by the telephone membranes replace the styluses of the graphic recorder previously described.

(*To be continued.*)

The Art of the Apothecary

Its Ancient Origin and Modern Development in France

By Jacques Boyer

THE maladies from which mankind suffers doubtless had their origin in the earliest eras of human life, and the idea of applying remedies to them must have entered the minds of our most remote ancestors, causing them to make trial, at hazard, of medicaments of whose healing virtues they were in ignorance. Then, when the experiment chanced to be followed by a cure, the same drugs were prescribed in similar cases. Thus were born in human societies the professions of the physician, the surgeon, and the pharmacist.

In an era nearer our own times there appeared in Egypt the class known as "*rhizotomes*," freemen who made a practice of gathering the plants used in therapeutics either on their account or for some professor of the art of healing. There appeared likewise the "*pharmacopoles*," or makers of vegetable extracts, and the pharmaceutribes, who confined themselves to assembling medicaments for sale. As for the products which were used in medicine from the time of Hippocrates to that of Galen and Avicenne, a considerable number are still employed today—opium and the poppy, among narcotics, wormseed (absinthe) as a febrifuge, eye-salves, cerates, unguents, pomades, etc. While the "Mithridate" (a preparation supposed to protect from poison and to act as an antidote therefor) and the "Theriaca" (an antidote for poison), which contained viper's flesh among other ingredients, are no longer regarded as universal panaceas, we still make use of the formulas of the Arab Geber for certain mercurial preparations.

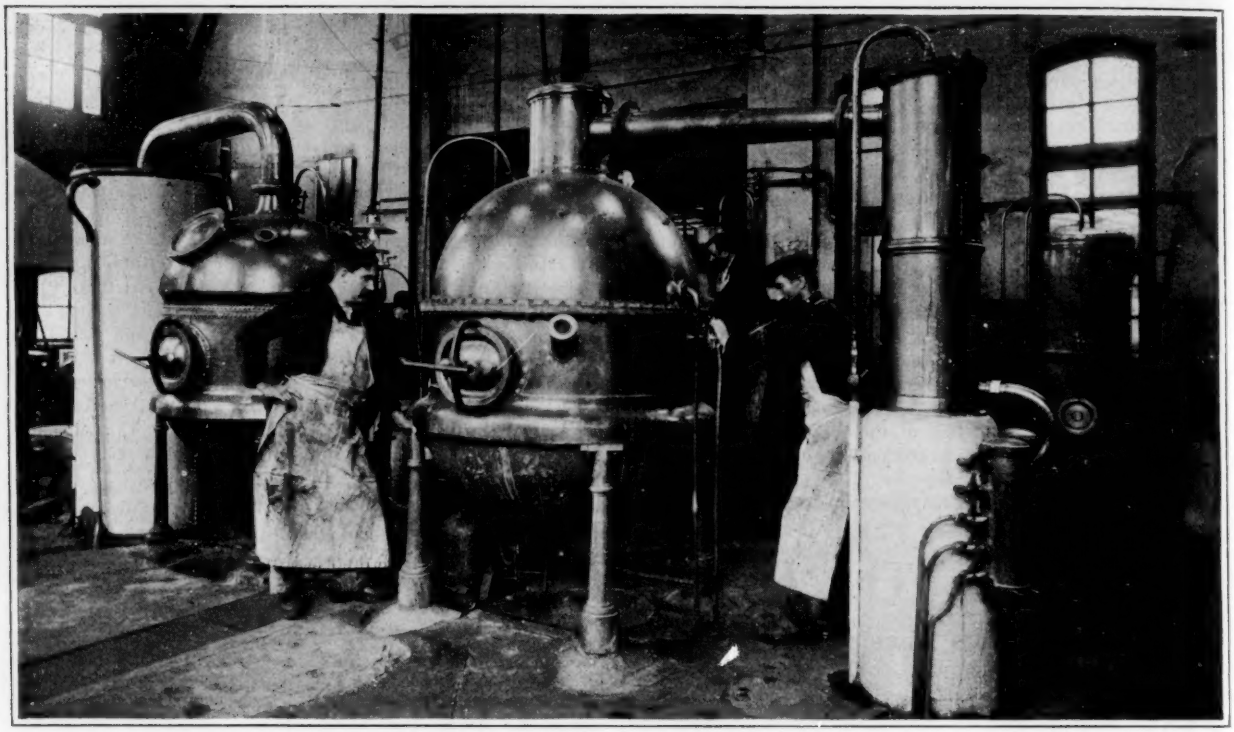
Furthermore the ancient officinal processes of Athens, Rome, and Alexandria much resembled our own. Infusion, decoction, expression, and distillation are currently employed. Modern instruments, to be sure, have been improved, but even in ancient times a well-equipped laboratory included the mortar, the slab of stone upon which to grind and crush materials, and the sieve, among other things. However, pharmacy underwent but slight development among the Greeks and Romans. In Gaul the Druids combined the practice of medicine with religion. They prepared from plants topical applications and various draughts.

Later, when one land had been penetrated by Christianity, the Druidical tradition was carried on by communities of monks. At once priests, physicians, and pharmacists, they had scarcely any rivals in the art of caring for the sick until the foundation of the School of Salerno. But at this period the Jewish physicians driven from Asia Minor by the Arabs, took refuge in France. They brought along, besides the Moslem art of therapeutics, their "Krabadin," a formulary whose composition dates from the ninth century.

However, the first official documents relating to French pharmacy which have come down to us do not go back so far. The existence of this art at Paris is indicated by an ordinance issued by Philipe le Bel (1311), who enjoined upon "grocer apothecaries" the possession of weights and measures. In 1336 Philippe VI le Valois issued an order to the deans and masters of the "very salubrious Faculty of Medicine" to take note of the character of "opiates and laxatives in order to make sure that they are fresh and of good quality." The same edict was issued for Montpellier in 1340. At Bordeaux an authentic record bearing the date of 1355 proves that in this city as well as in the other provinces of France the apothecary was also a grocer. In the following centuries we find that the profession was regulated, and the Swiss physician Paracekus (1498-1541) enriched the therapeutic arsenal with medicaments having antimony, arsenic, iron, potassium, zinc, etc., as their basic element. The ordinance of Charles VIII., not recorded until May 5, 1520, constitutes a veritable code for the apothecaries of Paris. From this we learn the principal conditions required to be fulfilled by candidates for this profession: First an apprenticeship of four entire years, after which they had to undergo an examination, and finally the composition of a "chel d'oeuvre."

In 1598 Jérôme Périer, Consul of the State, was charged with the editing of the statutes of the Corporation of Pharmacists of Montpellier. The municipality of Dyon had even antedated the capital in this latter point, and in consideration of "the public welfare, profit and utility" they confined the practice of pharmacy from the year 1490 to such persons as had undergone a successful examination before a jury composed of two aldermen, two physicians, and two professionals. About this time there were published the first treatises of pharmacy written in French, among others the "Enrichid or Manipul des Micopoles," by Michel Dusseau (Lyons, 1561) and the "Pharmaceutical Works" of Jean de Renow, both of which had a great vogue.

But while the intellectual level of the pharmacists rose to some degree their fights, now with the grocers, and now with the doctors, kept them from having an easy life of it. The battle was particularly lively at Lyons. However, it termi-



HUGE STILLS USED IN EXTRACTING QUININE

nated in their favor, since in 1571 Charles IX., acceding to the demands of the Lyons pharmacists, granted them two sworn masters, and then a code of 62 articles which underwent a number of revisions and was not definitely promulgated until much later. In 1638 Louis XIII. regulated the mode of reception of the future apothecaries.

To begin with there was a preliminary examination lasting three hours in the presence of six nurses, the two doctors delegated by the Faculty of Medicine, and six sworn masters. Next came the second test, the "act of herbs," and finally the manufacture of a "chef d'oeuvre" consisting of five compositions accompanied by interrogations. The young disciple was then permitted to take his oath and to "deliver his mark impressed upon lead to the the masters of the confraternity." However, since this ordinance established no requirement of responsibility on the part of the vendor of toxic substances a large number of poisonings occurred in the course of the XVII century. This legislative defect was remedied by the Grand Monarch in 1682. By this edict he interdicted the distribution, by masters of pharmacy and by grocers, of arsenic realgar, corrosive sublimate, and other dangerous drugs, except to persons known by them. Each official laboratory was required furthermore to possess a register initialed by the public magistrate upon which the purchasers were obliged to inscribe their name, rank, and residence, the month and the day, the quantity of poison carried away, and the purposed use thereof.

The corporation counted among its members at this time many eminent savants among whom may be mentioned the German Glauber, who discovered in particular the sulphate of ammonia, kermes, and the sulphate of soda; Seignette, the Rochelle apothecary who first obtained in 1662 the tartrates of potassium and of sodium, the purgative still employed both in the old world and in the new; and Nicholas Lémery (1645-1715) a humble apothecary of the Maubert quarter who instituted at Paris the first course upon chemistry with experiments, and whose work entitled "Universal Pharmacy" (1697) was the *vade-mecum* of several generations of students.

The rivalry between French physicians and pharmacists attained its climax about this time. Guy Patin was one of those who were most infuriated against those whom he termed with disdain the "*fricasseurs* [this word means either a bad cook or a worthless waster in general] of Arabia," and the letters of the irascible practician have brought down to our ears the echos of those heroic-comical battles which doubtless inspired Molierè. However this may be, and in spite of the treaties of peace signed between the parties a sullen hostility reigned for nearly a hundred years more between the "*limonadiers des postericurs*"—as Vade called them in a vulgar jest—and the Faculty. Fortunately there appeared in 1777 the famous ordinance of Louis XVI., which, separating the apothecaries from physicians, grocers and druggists, gave uniformity to the practice of pharmacy throughout the kingdom and put an end to these secular disputes. It is from this year that the College of Pharmacy, which became the only seat of instruction at Paris, dates. It is proper to add that this was, on the whole, a mere transformation of the school founded by a former practician of the Capital, Nicholas Houël in 1578 in which there existed an embryonic form of instruction given by benevolent apothecaries.

Under the revolution charletanism was able to flourish since the decrees of 1791 had proclaimed the freedom of commerce; but following upon the occurrence of numerous accidents the National Assembly decided to maintain in force the former pharmaceutical regulations; however such abuses continued to occur until the promulgation of the law of Germmial 21, year XI. (April 11, 1803) which created six schools of pharmacy for the whole of France and treated of the mode of reception and of the practice of the profession. The main features of this still exist with modifications which are of interest only to members of the profession. We may mention in particular that since 1899 there has been no pharmacist of the second class in our country; the sole professional diploma is that of the first class.

From the end of the XVIIIth century until our own time, pharmacy has benefited by numerous scientific discoveries, more than one of which issued from the crucibles or retorts of skilled apothecaries. In this modest laboratory at Koeping did not the Swedish Scheele (1742-1786) isolate chlorine, so important in matters of health, and glycerine, whose applica-

tions in medicine are multiple? Baumé made popular areometry, universally employed since his time; Robiquet discovered caffein; Pelletier and Caventon became famous by the preparation of the sulphate of quinine (1828). Finally, nearer our own day, we have as a result of the memorable researches of Pasteur (1822-1895) and his pupils, the introduction of serums into current therapeutics. Thus progress has given a new orientation to the profession of pharmacy. These medicines, often of highly complicated formulas, these biological or other products prepared under the laws of asepsy or antisepsy, these animal serums, can no longer be made in the back room of an apothecary shop. Their manufacture must be monopolized by a few great factories by Pasteur Institutes or by physiological laboratories.

This is an accomplished fact today. The accompanying photographs will enable us to penetrate these little known establishments where remedies which are employed in infinitesimal doses—such as quinine, for example—are obtained in hundreds and thousands of kilos.

How modest seem the utensils of the apothecaries of old compared with these gigantic vats where sulphate of magnesia is crystallized; or with these enormous alembics where quinquina and cocaine are being elaborated; or with these heavy mortars and stout pestles which crush benzoate of soda all day long!

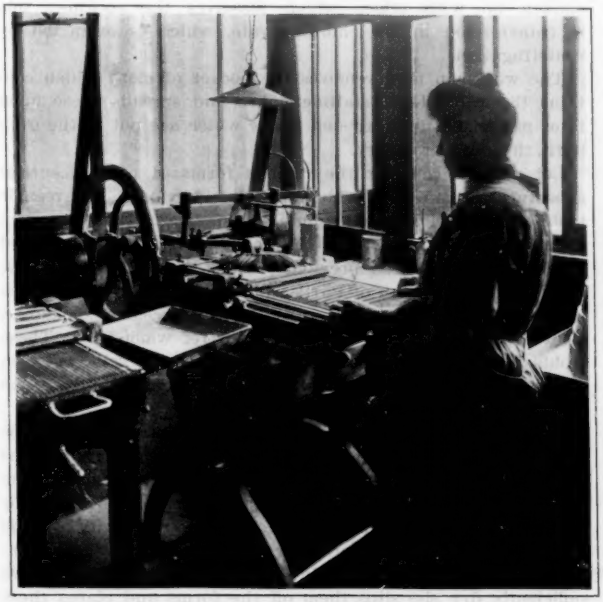
As a matter of fact the raw materials furnished by nature are rarely capable of direct use in the art of healing. They must undergo various manipulations whose object is to facilitate the method of administering them to the patient—in a word, to sugar the pill for the invalid! Let us make a rapid review, therefore, of the principal modern methods by which the various pharmaceutical forms are obtained:

In the herbarium, a more-or-less extensive storehouse, are kept the wood and barks, the freshly gathered plants are either spread out or hung up to dry; when completely desiccated they are placed in carefully labeled packages until such time as they undergo division by means of shaving machines (sandal wood, quassia), by triturators (the granulation of cinchonas), by winnowing-machines and mill-stones (linseed meal); or until they are pulverized in cast iron mortars by mechanically operated pestles; or until they are ground between granite mill-stones or sifted in order to obtain a powder of the degree of fineness exacted by the codex.

Distillation is employed in the preparation of the hydrolates and the alcoholates—*i. e.*, those medicines in which water and alcohol respectively constitute the vehicle of the basic medicinal substance. In the majority of cases vegetable substances are employed either while fresh or after desiccation. They are macerated for a period which varies from 24 hours to several days, then placed in a retort and distilled over a water-bath. Sometimes the distillation takes place in a vacuum, which considerably lowers the boiling point and prevents the decomposition of the essential oils. Let us take as an example the method of obtaining the valuable febrifuge quinine. It is extracted from the bark of the cinchona, which is first broken up, pulverized and sifted by mechanical means, and then mixed with a certain amount of lime; the mixture is then extracted by heavy petroleums in a vacuum retort.

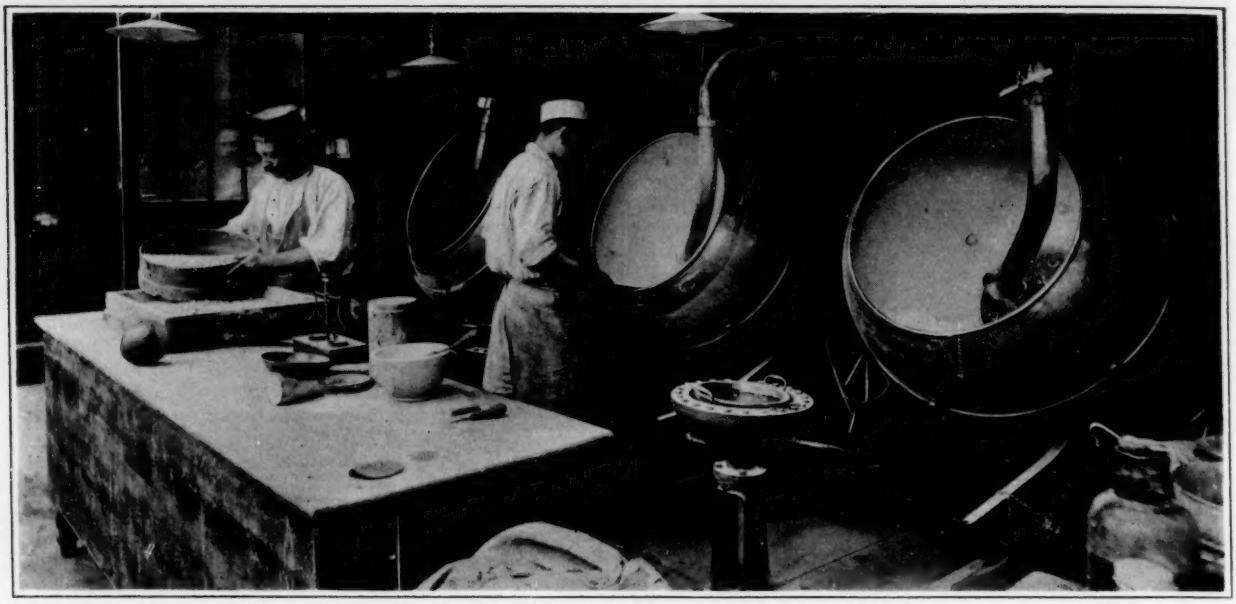
As a usual thing underground pipes deliver the hydrocarbons to the apparatus. Pumps deliver the quantities needed daily into an enormous cistern so as to avoid the accumulation of inflammable substances in the work-shops. Cinchonine and quinine, the alkaloid which the cinchonas contain, are dissolved in the petroleum, from which they are liberated upon cooling. They are separated by converting them into the sulphate which is then allowed to crystallize in huge vats. The sulphate of quinine is deposited, while that of the cinchonine, being more soluble, remains in the mother liquor. Complete purification is secured by successive crystallization, after each of which the product is collected in powerful centrifugators which rapidly eliminate the mother liquor. Finally the purified sulphate of quinine is spread upon wicker-work covered with absorbent paper and placed in an oven. After being thoroughly dried the product is ready to be packed in bottles or boxes.

Dry or soft extracts are obtained by the more or less complete evaporation of a solution of an animal or vegetable product in order to reduce to a comparatively small volume the active medicinal principles it contains. Although the discovery of the alkaloids, acids, glucosides, and other definite compounds contained in plants has diminished the importance of the extracts, basins having a capacity of 230 to 500 liters and retorts holding 1,500 liters are often used for preparing the aqueous extracts of cocoa, of kola, of digitalis, and of opium; the alcoholic extracts of colchicum and of hyosciamus; the etheric extracts of cantharides and of the male fern. As for the extracts termed "robs" they are obtained by the direct



THE "MAGDALIONIER" FOR MAKING RODS WHICH ARE LATER FORMED INTO TABLETS

FILTERING LIQUIDS ON WOODEN TRAYS IN THE KERMES LABORATORY



HUGE CALDRONS IN WHICH PILLS ARE SUGAR COATED

evaporation of the natural juices of plants, such as those of aconite, lettuce, belladonna, and hemlock.

Let us now attempt to obtain an idea of the importance of the production of certain medicines derived from the mineral kingdom by chemical means. Let us enter the kermes workshop in the "Central Pharmacy" of France at Saint-Denis, where we may see 25 sheet iron vats having a capacity each of 1,200 liters, provided with pipes of large diameter and with stopcocks by means of which they can communicate with each other or be shut off at will.

Herein there is boiled for one hour a mixture of sulphide of antimony, carbonate of soda, and water, which is then allowed to pass into the evaporators that have a capacity of 5,000 liters. The liquid is filtered while hot and upon cooling there separates from it a brown, light, velvety powder which is placed upon wooden wicker-work covered with paper to dry; this powder constitutes the kermes which is used in doses of 5 to 20 centigrams as an expectorant. Not far from this room, in the same factory is a furnace wherein from 5 to 6,000 kilos of magnesia are annually calcined—*i. e.*, a quantity sufficient to purge 4 or 5 hundred thousand persons! The washing of the carbonate of magnesia requires 20 vats each having a capacity of 2,000 liters and the desiccation of the cakes of this salt is accomplished upon shelves arranged in a vast oven.

Equally large are the vats heated by steam in which the solutions of sulphate of magnesia are daily evaporated. From these troughs conduct the liquids into the crystallizers, where they are transformed into pretty, white crystals which are removed by workmen with mallets. Eighty thousand kilos per year of this salt are manufactured at Saint-Denis.

Chloroform alone often occupies a separate room whose windows are provided with black curtains. In order to prepare it 10 kilos of the chloride of lime are mixed in a roomy retort, with 3 kilos of slacked lime in 80 liters of water; to this mixture two kilos of alcohol are then added and the whole heated by means of a current of steam, care being taken to have the container only about one-third full. At about 80° C. the mass begins to seeth and almost pure oxygen is liberated. At this moment the fire is extinguished and the distillation begins. As soon as the boiling stops a second quantity of the first mixture is introduced into the retort, and so on until it is full. The heating process is then begun anew and a product is collected which consists of chloroform, water and alcohol; after being condensed in a worm this product flows into a metal container. Since the chloroform is denser than the two other substances it is easily separated; it is then washed with water and with potassium carbonate, afterwards being dried over calcium chloride. Since the final product must be extremely pure in order to avoid accidents in the course of surgical operations it is necessary further to rectify it by shaking it up with sulphuric acid, washing it with a soda solution, and then, after stirring up with pure oil of cloves, redistilling once more, removing the first and the final products.

We must not leave the anesthetics without describing the apparatus which is employed to extract the leaves of cocoa in order to obtain cocaine, which also renders excellent service to modern surgeons and dentists. As soon as the liquid has been extracted and filtered it is precipitated by the acetate of lead; then, after removing the excess of the latter by means of the sulphate of soda the resulting compound is shaken up with ether, which dissolves the cocaine; this is transformed in the chlorohydrate, which is extracted by centrifugation.

The workman then removes the pocket of cloth which contains the valuable crystalline flakes and spreads these upon filter paper laid upon wooden plates which are put in the oven until the product is dry.

Let us now consider the various forms of pharmaceutical substances by means of which medicines having a disagreeable taste or odor can be easily administered. Formerly it was considered sufficient to envelop bitter powders with unleavened bread which had been previously moistened. But about the year 1872 a practician of Paris named Limousin conceived the idea of enclosing them in capsules of the same substance. They are now made by means of a sort of waffle-iron. These molds consist of iron plates containing small cells between which a starch paste is introduced, and they are set on a gas stove.

The same purpose is served by capsules having an envelope of gelatin. The envelopes are made by inserting iron forms shaped like olives in a solution of gelatine and gum. The stems of these "olives" are held in a plate which the operator rotates back and forth so as to secure regularity of the viscous layer which adheres to the forms. She then withdraws the forms from the solution and when the capsules are sufficiently dry she slips them off the forms and places them orifice upwards in sockets formed in a board, to be filled with the desired liquid. When the capsule is full it is closed by

passing a brush dipped in the gelatinous solution several times over its orifice.

Another process which is widely employed for ether, spirits of turpentine and other highly volatile substances was invented by M. Thévenot. The liquid is poured between two plates of solidified gelatine whose edges are welded together

BOTTLING COD LIVER OIL

by enclosing them between the two jaws of an indented metal mold, which is placed in a hand-press. In this manner beads are obtained having the form of a flattened spheroid; these beads are readily separated from each other by hand upon issuing from the machine.

Lozenges are made by the aid of an ingenious apparatus. A paste is first prepared of the pulverized or dissolved medicament incorporated with sugar by means of gum tragacanth. This paste is then malaxated and rolled out. It then passes between two series of cutters which automatically cut it into pastilles. In order to prepare the paste of marsh-mallow or of lichen the medicinal substance is incorporated with melted sugar and then introduced drop by drop into special molds by means of a dropper. The molds are made in the following manner: Rectangular wooden boxes are filled with powdered starch and then placed beneath a press which forms a series of holes in the starch and into these the fluid paste is introduced.

The manufacture of pills is accomplished by means of pestles and of the "magdaleonier." The first step is to mix the active substance by means of mechanical pestles, which consist of enormous vertical beams covered with a heavy mass of metal. These are given a rotary motion by means of suitable gearing. As soon as the product has been pounded to a suitable degree of fineness, in case it has to be pulverized, there is added to the glycerine solution a syrup, an extract, or some other agglutination, in order to give it the proper consistency. If, on the contrary the mass is liquid or too soft an inert powder is incorporated with it. The paste is now ready to be formed into pills. For this purpose it is rolled into "magdaleons" or cylindrical rods which are compressed between the superposed grooves of a machine, called a "magdalonier." The small balls thus obtained are preserved in lycopodium powder in order to prevent them from sticking to each other. Then the balls are rolled out into tablets.

Sugar coated pills are obtained in a manner almost identical to that in which ordinary bon-bons are made, except that the nut is replaced by an agglutinated preparation—iron, mercury, anise, digitaline, atropene and other active principles. The kernels are placed in a caldron called the "Branlante" which is heated and has a rotary motion. Into this gum dissolved in a little water is gradually poured and then a perfumed sugar syrup is slowly added. The kernels are covered with this mixture by rolling against each other, and by the adding of fresh syrup a number of times they gradually become covered with a sugar envelop. They are whitened by adding a little starch to the mixture end are finally placed in the oven to dry.

Let us now leave the confectionery room and descend into the cellars of the great drug factories, where the oils, balms, and unguents are manufactured. Let us first glance at the great cylinders made of galvanized sheet iron, which have a capacity sometimes of 1,200 liters in which cod liver oil is delivered directly through an opening in the floor of the warehouse above, just over each of its containers. After the first period of settling the oil is allowed to float into huge cisterns each capable of holding 6,000 liters; afterwards it is pumped into filters which distribute it into huge vats lined with zinc and ranged along the wall of the ground floor; the spigots of these pass through a partition into another room, where operators are employed in bottling, corking, and labelling the oil or putting it into capsules.

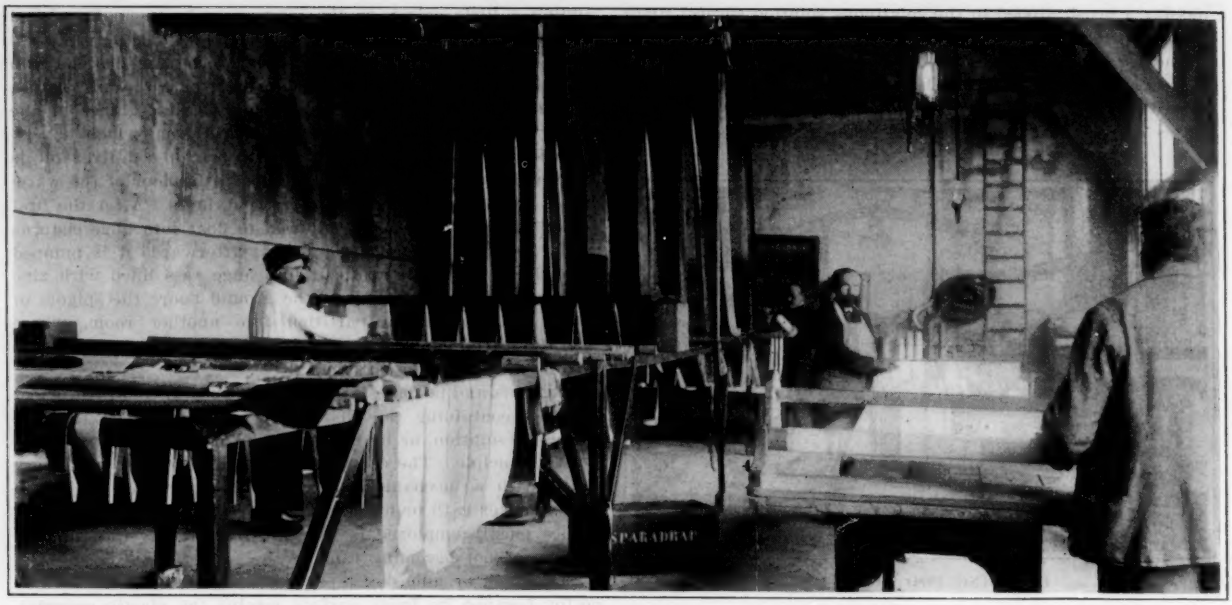
Unguents and pomades are often prepared in cellars adjacent to those containing the oils, either by a simple mixture, by means of solution, or by boiling the fatty substances with the active principle. The container is usually a copper basin provided with a mechanical mixer. This basin can be heated over a water bath or not as the case requires. The fatty substance mostly employed is vaseline, since it has the valuable quality of not becoming rancid.

Sparadrap or adhesive tape is usually made of unbleached cotton because its fuzzy surface retains the plastic material, but silk is likewise used. The cotton is cut into strips 5 m. long and 20 cm. wide, and the melted plastic material is then poured over it. The adhesive bands are dried in the open air and then rolled and placed in boxes.

Since the admirable researches of Pasteur and Koch and of Roux, it is a well-known fact that injection of the blood of an animal immune to a given infection into the veins of other living creatures which are susceptible to the same malady, renders the organism of the latter more resistant. For this reason modern practice gives battle to many morbid infectious conditions, such as cholera, small pox, dyphtheria, variola, or tetanus, by means of anti-microbian serums extracted from

FILLING GELATINE CAPSULES

the blood of animals which have been previously rendered immune. Such products are prepared in special scientific establishments. For example, physicians procure from the Pasteur Institute anti-diphtheric and anti-tetanic serums which are obtained in an annex situated at Garches (Seine et Loire). At this place a hundred horses are kept, in which culture of



MAKING SARADRAPS OR ADHESIVE BANDS AND TAPE

the microbes of diphtheria or of tetanus are injected. As soon as these animals have been rendered immune their blood is collected by means of a trocart induced into the jugular vein and a rubber tube connected with a receptacle which has been previously asepticised. This container is then carried into a cool cellar and after a lapse of, at least, twenty-four hours the serum can be extracted by simply siphoning off the liquid.

Such medical preparations are derived from special laboratories where pigs annually "manufacture" gastric juices, known commercially under the name of dyspeptine or pepsin. Dr. Maurice Hepp was led to found this establishment because he had succeeded in curing many of his patients afflicted with serious stomach troubles by means of the so-called gasterine of Frémont (the gastric juice of the dog). He therefore resolved to study the question further in order to avoid certain inconvenient features involved in the use of gastrene, especially of its too great acidity. After many fruitless experiments he successfully replaced the dog by the pig, which has a stomach of very considerable capacity as well as highly remarkable powers of assimilation and whose gastric juice is very similar to that of man, being only slightly acid. He began by studying the various modes of operation which might enable him to collect the living secretion and finally decided upon the following: He excludes the stomach from the alimentary canal by cutting the oesophagus above the cardia and connecting it with the duodenum. He then produces a gastric fistula through which the secretion can be drawn off.

When a pig is operated upon it is placed upon a surgical table and chloroformed, for, as one can readily understand from the description this operation is very long and serious in character. Thanks to this surgical invention the food taken by the animal does not pass through the stomach which continues, however, to secrete the gastric juice abundantly at the very moment of the food's ingestion.

The subject of the operation recovers after a very short lapse of time and in order to collect its gastric juice it is only necessary to suspend the animal by means of a special harness about forty minutes after its meal and introduce by means of its fistula which has been previously asepticised a tube which delivers into a flask a considerable quantity of the secretion, while the surplus passes into the deodenum through the pylorus, which remains open thus maintaining the proper physiologic function of the patient. That this is true is proved by the fact that upon the farm at Puits d'Angle where the Hepp "dyspeptine" is manufactured, one finds animals which have lived for three years and more in spite of the stomach fistula and which steadily increase in weight. The gastric juice thus collected is turbid and since it contains an enormous microbian flora it is nesessary to filter it under a slight pressure of carbon dioxide. Dr. Hepp makes use of carefully sterilized filters and the extracted juice issues from these perfectly limpid and of a pale amber color. After being bottled for a fortnight a powder is deposited upon the bottom of the flask. A little bit later the product melts under the influence of luminous rays.

Finally if we would speak of all the "factories" which supply modern pharmacies, it would be necessary to describe other enormous establishments also; for example, the one at Bourg-la-Reine, which is similarly devoted to the sterilization of absorbent cotton, bandages, cat-gut and other surgical material—workshops where bandages and other orthopedic materials are continually turned out. But we must bring this brief story to an end since the remedies devised to alleviate our physical sufferings are innumerable, merely remarking that many of them affect our purses more than our ailments.

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EXTRACTING PEPSIN FROM A PIG IN A VIENNA LABORATORY

Preventing Rail Fractures Resulting from Minute Fissures*

"Ageing" Metal Restored by Annealing

IT has been frequently observed by many investigators that iron rails are often fractured, though containing no defects due to the process of manufacture, because of the formation of very fine fissures upon the rolling surface after the lapse of a certain amount of time. Most authorities who have called attention to this phenomenon have recommended a minute examination of the road bed from time to time, for the purpose of removing rails which have undergone this alteration. Very recently, however, the question has been studied from a new angle by MM. Georges Charpy and Jean Durand. They have endeavored in the first place to determine the method of formation of these minute cracks and secondly to reproduce them artificially, with the object of discovering some means of preventing their production which should be at once less costly and more certain than the mere process of removing the affected rail.

In the course of their researches, an account of which was recently presented to the French Academy of Sciences, they proved to begin with that the phenomenon is very general in occurrence, being by no means confined to rails. This phenomenon is found in a large number of cases whose common characteristic is that the steel has been subjected to an intense degree of "hard hammering" or pounding, which has been limited to a superficial stratum. Under such conditions this stratum appears to be subjected to strains of the same sort as those which are produced by the interplay of movements of expansion between a ceramic paste and its covering, and which give rise to fractures from what are called "tremors" or vibrations. The cracks in steel are produced when the surface of the metal has been sufficiently hammered to cause it to break without undergoing perceptible elongation.

As might be supposed from the foregoing remarks the phenomenon is particularly well marked in the case of very hard metals. In the case of white cast iron, in particular, it only requires a rather rough rolling to cause the appearance upon the rolled surface of a network of fine cracks, very similar to that observed upon rails. The same experiment (the production of cracks by rolling) can be repeated with tool-steels which have been rapidly tempered, as well as with hard chrome-nickel metals (metal for shells).

These fissures, which are often extremely minute, can be accenuated by treatment with acids. It even appears to be true, according to the present authorities, that in certain cases the acid "develops" these fissures which existed in the metal in a latent state, being so slight, however, as to be undiscernible by the most minute microscopic examination of the polished surface; in such a case the cracks will be produced as soon as the resistance of the superficial layer has been sufficiently reduced by means of the thinning action produced by the action of the acid.

Analagous results can be obtained by other methods. We will cite one example only, which is, however, very striking in character. This consists in hammering the surface of a very hard metal by making upon the said surface the imprint of a ball by impact, according to the manner adopted in measuring hardness by the Brinnell method. Under such conditions one sometimes sees very fine fissures upon examining the imprint of the ball under the lens of a microscope; but even when the metal appears to have remained perfectly compact it is only necessary to attack it with acid as described above in order to observe well defined radiating fissures, which are usually arranged in the form of a regular star. The length of these fissures would seem to indicate the extent of the hammering produced by the ball around the imprint itself. This experiment succeeds admirably with rapidly tempered tools or upon the points of bursting-shells.

In the steel of average temper which is used for rails (having a resistance of from 65 kg. to 70 kg.) the total surface hammering is much more difficult to obtain; the work of rolling is powerless therefore to produce this result. In order to reproduce the phenomenon observed on railway tracks we, therefore, conceived the idea of making us of the analogy which exists, as long ago pointed out by Duguet, between the rolling of trains and the work of the rolling mill. The test is all the more readily made since rolls are frequently employed which are made of a semi-hard steel of a temper identical with that of which rails are made. But in a great number of these rolls we have been able to observe, after they have been in service for a certain length of time, cracks which are strictly identical with those produced upon the rails.

We have also observed the same phenomenon upon the trunnions of steel rolls.

It is worth while to mention here another example which at first glance appears to be very different from those described above: this is the phenomenon of the erosion of the bores of cannon which have been made the subject of various studies, including in particular the quite recent researches of Professor Howe and of Mr. Fay. Upon examining the surface of the gun bore at the moment when the erosions first begin to appear, one readily recognizes the presence of fine cracks which are identical with those of the rails and rolling cylinders described above, and which may be attributed to the hammering or rolling action of the projectiles upon the riflings.

This example, as well as that of the mill rolls, leads to the belief that the formation of cracks in semi-hard steel occurs much more readily at a temperature above normal. There is nothing surprising in this, however, for it has long been known that hard hammering is particularly dangerous for steel at those temperatures at which the metal is colored by oxidization (hard hammering at the blue heat). In the case of the railroad rails this condition may occur, indeed, in the slidings caused by sudden applications of the brake, under which influence a considerable elevation of temperature is produced, as we know.

The above observations indicate also that in the case of semi-hard steel the hammering required to occasion the formation of cracks can not be instantaneously produced, but necessitates a series of repeated actions which produce a gradual hardening of the surface. This view is corroborated by statistical relief maps. A very complete map of this sort has been received by me from M. Euverte of the P.L.M. railway system. If upon this map we place the curve representing the number of fractures of rays in function of the duration of the service, we find that it exhibits a sudden change of direction after a lapse of about ten years, after which time the number of fractures, which was previously very small, rapidly increases. We are here concerned, therefore, with a progressive "ageing" of the rails, in which ten years represent a "critical age" so to speak, at any rate in the case cited.

This observation enables us to discover a remedy for this condition. As a matter of fact the hardening produced by the hammering can be constantly suppressed from time to time by a suitable annealing; if this annealing is effected before the cracks have been formed the alteration produced is completely annulled—in other words the effect of the ageing process is suppressed, and we may say, therefore, to carry out the metaphor, that we have affected a "rejuvenation" of the metal which practically restores it to its original condition. This deduction can be readily illustrated by means of the experiment cited above concerning the impression made by a ball upon hard steel. If after having made the impression the metal is

*Translated from the *Comptes Rendus* of the French Academy of Sciences for the *Scientific American Monthly*.

annealed we find that it may be attacked to great depth by an acid without occasioning the slightest appearance of a fissure. This superficial annealing is comparatively easy to apply in the case of rails. Descriptions have recently appeared of ovens mounted upon wheels devised for the purpose of producing superficial tempering of the rolling surface of railways. The same apparatus can be used for annealing even more readily. If this annealing be done before the critical age of ten years is reached there is every prospect that it will be possible to diminish very considerably the number of fractures due to cracks. Without further insisting upon this view to which we hope to return later, we feel it advisable to point out its very general character. Whenever a piece of metal is liable to undergo alterations by means of local hard hammering, which develops gradually in the course of service—and examples of this are very frequent, not only in rails but in chains, bolts and pins, braces, etc.—this effect may be counteracted by annealing at suitable intervals. To continue our figure of speech we may say that the "duration of life" of certain pieces of metal may be considerably prolonged by "thermal cures" applied at suitable intervals. Needless to say we have here a possible means of economizing metal which should not be neglected.

WIND-POWER ELECTRIC PLANT

MR. JANSON, of Sweden, has erected a new windmill near Stockholm for the purpose of generating electricity. The irregularity of the wind is equalized by compelling it to raise a heavy weight to a considerable height and the energy developed as it falls being utilized to drive a dynamo, instead of the usual direct drive.

The mill wheel has four 18-foot sails which make 30 revs. per minute. The total surface exposed to the wind is 244 square feet, and produces 6.22 h.p. when the wind has a velocity of 23 feet per second. The wind-motor and dynamo are mounted on a bracket on the top of a 20-foot steel mast, and turn automatically to the wind. The mast is in turn supported from a timber structure 33 feet high, the lower portion of which, together with a ground surface of 269 sq. feet, are roofed over to a height of 11 ft. 6 in. for housing the switch-board and storage battery. This consists of 65 cells with a capacity of 150 ampere hours when discharging at the rate of 45 amperes. The current is used for lighting a manor house and for agricultural machinery. The 2-ton weight used to drive the dynamo is suspended from a chain and raised by a special gear. The arrangement is very sensitive, and even the slightest wind will raise the weight slowly through an automatic variable speed gear, while a ratchet wheel and pawl prevents any reversal of the moment.—*Gustav Sellergren* in *Tekrusk Tidskrift* (Sweden), abstracted by the *Technical Review*.

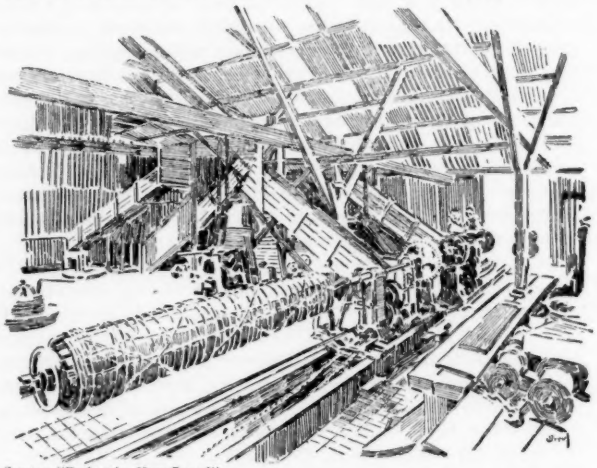
REINFORCED-CONCRETE PIPE MADE BY THE CENTRIFUGAL PROCESS.

CONCRETE pipe which have been tested without serious rupture for an interior water pressure up to 400 lb. per square inch are being made by the centrifugal process for a number of uses in Australia and South Africa. The method of manufacture was developed by W. R. Hume, of Adelaide, South Australia, and the pipe are being made under concessions from him. In brief, the system consists of whirling a pipe mold full of concrete on a horizontal mandrel, trusting to the centriugal action to compact the concrete.

The pipe are being made in 4-, 6- or 8-ft. lengths. The reinforcement is of wire. In South Africa old steel winding ropes from the mines are heated, to anneal and soften the wires and to burn off grease. They are then wound in various ways upon revolving cylinders of the same diameter as the inside of the pipe, a sort of ropewalk being used for unwinding the strands of old rope.

The mold consists of a flexible 1/16-in. steel cylinder cut in half lengthwise and re-joined by hinges and clamps, so that when it is opened the pipe can be removed. This mold is placed horizontally on the rotation friction rollers of the casting machines. When a pipe is to be made, the steel wire reinforcement is placed inside the mold. Flanges, the same depth as the required thickness of the pipe walls, are placed on the end of the mold, and wet concrete of various grades corresponding to the quality of the pipe required is introduced from the ends, which are open except for the flanges mentioned. The pipe is revolved slowly at first, and the concrete is automatically distributed evenly along the whole length of the pipe and around the circumference, and completely incases and embeds the reinforcement.

The pipe is then revolved more rapidly, and the excess water, with any impurities, is collected in the center of the pipe and drawn off at the ends. Pipe of 4-in. diameter can be "spun" out at the rate of one per minute. Pipe 6 in. in diameter take 2 min.; 18-in. diameter take 8 min., and 48-in. diameter 20 min. The concrete by this time has set so hard that it is impossible to make an impression on it with the finger. The molds are run into a steam house for 24 hours and then opened, and the pipe are seasoned in water tanks for a month, usually. Pipe can, however, be put to use within a week. The pipe show a remarkable density, and are impervious to great pressures either in sections or as a continuous line. A joint as strong as or stronger than the main itself has been designed. The ends of the pipe are recessed and butted together, forming a diamond-shaped cavity between

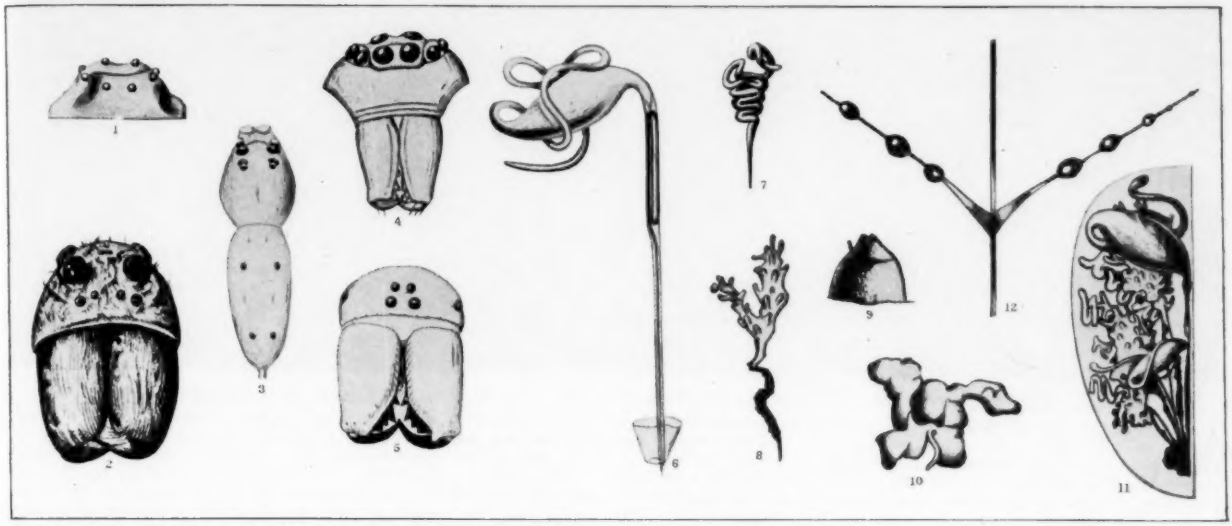


Courtesy "Engineering News-Record"

REINFORCED-CONCRETE PIPE ON A MANDREL IN THE SHOP

them. A collar 6 in. wide, of strength similar to that of the pipe, it put on and secured with a backing of cement at both ends. Between the pipe a plastic bituminous cement is inserted, and pressure tends to compress this in the annular cavity of diamond-shaped section. This makes a joint which has been tested to 400-lb. pressure. Experiments show that a pipe designed for 100-lb. pressure shows at 200 lb. faint lines of dampness; at 250 lb. this becomes a dew. At 300 lb. the dew develops into a heavy sweat, and at 350 lb. jets of the finest misty spray appear. If this pressure is reduced the pipe takes up and is as capable as before of carrying 100-lb. pressure.

Until 1916 there was considerable skepticism concerning the suitability of these pipes for high pressure. In that year J. C. Ross, city engineer of Hobart, recommended the installation of 10 miles of 18-in. pipe to pass 13,000,000 gal. of water per day under a head of 250 to 350 ft. This line was successfully laid with a saving of $15,000 over cast iron, and the pipe is now almost universally used in water-supply and irrigation projects in Australia. Cylinders 10 ft. long and 6½ ft. in diameter are being made by this process for use in harbor works at Burnie, Tasmania, and cylinders 15 ft. in diameter have been made for use as buildings and silos.—*E. M. Weston* in *Engineering News-Record*.



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SPIDER FACES AND SILK-SPINNING ORGANS

1. Model showing anterior row of eyes recurved. 2. Licosa carolinensis; eyes in three rows. 3. Eyes in four rows; Lysomanes. 4. Face and cheliceræ of Theridion. 5. Face and cheliceræ of Aranea. 6. An ampullate gland. 7. Cylindrical gland. 8. Aggregate gland. 9. Hind spinneret of Steatoda. 10. Lobed gland. 11. Section of abdomen showing silk glands.

Spiders as Mechanics*

Their Skill as Weavers, Miners, Builders, and Aeronauts

By Professor E. L. Bouvier

Member of the French Institute, Professor at the National Museum of Natural History in Paris

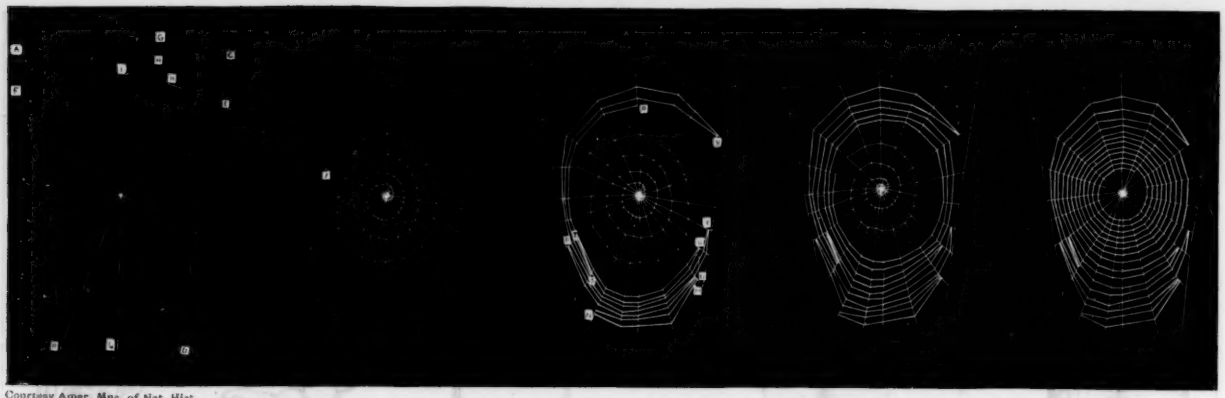
WHO has not seen and admired the marvelous vertical orb-web made by those gifted spiders which are called indifferently *Acaneus* or *Epeira!* Radii spaced at equal distances form the framework and connect it with the helix where insects are captured and which adheres tenaciously to the radii, and from the center where the latter converge there starts a guide line which, connects them with the ordinary retreat of the animal. In the case of the diademed *Epeira* (*Araneus diadematus*) this is a simple shelter formed by a few leaves loosely held together, while in the *Araneus quadratus* it is a silky shell-like structure with an opening beneath. Lurking at his post with one hand, so to speak, upon the guide line, the spider perceives the slightest tremor of the web. Has an insect been caught in the net? If so, he runs down the guide line until he reaches it, binds it fast, and slowly sucks its sweet juices, on the spot if it is small, but in his retreat if it is strong. At the time when the eggs are laid it fastens a cocoon packed with eggs to some plant in the vicinity; and when the young issue considerably later from the silky envelop they at once begin to spin threads which float in the air and carry the daring aeronauts hither and yon.

Silk and Spinnerets.—While silk does not play so important a part among all spiders they are all capable of producing it, at least at the period when the eggs are deposited. This property is characteristic of the chitinous animals and is observed in all their groups, at any rate among certain species, and in particular among the larvae or caterpillars of butterflies; but nowhere is it so general and so skilfully turned to profit as among the spiders.

The silk is a glandular secretion which may be extended into solid threads as it is emitted by the *spinnerets* from which it issues. The larvae of insects have usually only one spinneret which is situated upon the lower lip and from which issues only a single thread. But spiders possess several which are situated at the rear upon the ventral surface of the abdomen, and each of them bears a variable number of tubuar hairs or *fusules* which serve as vector conduits to an equal number of small silk-producing glands. Being produced by the partial or total fusion of all these elementary threads, the finished thread of the spider is complex in origin. The spinnerets which elaborate it are articulated appendices which vary in length. Four pairs are possessed by the *Piphistiidae*, which are exotic *Arachnidae* in which the abdomen has retained its dorsal segmentation, while they are reduced to two pairs in the closely related *Aviculariidae* or *Mygalas*. On the other hand the *Uloboras Dyctinas, Eresus* and similar forms preserve the totality of these organs, having, moreover, a modification of the spinneret of the first pair, which are contiguous, project only very slightly, and form together with their fusules a small protuberance called the *cribrellum*. The other spiders, which are by far the most numerous, lack this organ and, furthermore, possess only three pairs of spinnerets which are all grouped in front of the anus.

The silky threads are of different kinds but are usually cylindrical and are fine or coarse according to whether they result from the elementary threads produced by the fusules or from the coalescence of these: in the suspending cable of the orb-webs several coarse cylindrical threads may even be juxtaposed. The permanent helix of the orb-web of the Epeiras is entirely formed of a *viscid thread* which is composed of a solid cylindrical axis and viscid globules which hold fast the insects which are the spider's victims; these globules are very hygrometric and dissolve in rain water, while on the other hand, they slowly harden in the sun; it is by means of these that the web functions as a snare. Among the cribrellate spiders the same rôle devolves upon threads which are produced by the cribrellum and are made flocculent by a sort of comb, the *calamistrum* which occupies the penultimate joint of the hind legs; in the *Uloboras* which weave a horizontal orb-web, the *calamistral threads* which are rolled around an axial thread constitute the helix where the insects become entangled.

*Translated for the Scientific American Monthly from *La Revue Scientifique* (Paris).



Courtesy Amer. Mus. of Nat. Hist.

MODELS SHOWING THE PROCESS OF WEAVING THE WEB OF EPEIRA SERICATA (SCLOPETARIA)

The spider started from a branch *a* (first plaque at left) and dropped to branch *b*, spinning a thread and fastening it. She then climbed on this thread to the upper branch, crossed over to the point *c* and dropped to a point *d*, making the strand as before. Then going to *e*, she fastened one end of the strand and spinning it behind her, went across by way of the upper branch to *f*. She then went to the upper branch and dropped to this *e-f* strand fastening the new line at point *h*. This pulled *e-f* up slightly. The next strand which she put in was from *i* to a point on the lower branch below *j;* pulling this line made another angle in the cross strand *e-f* as did the following line from *k* to *b*. These last two strands were fastened near the center by a bit of silk, and the remaining radii were put in by moving about on the foundation of the web. The next step in the operation was the laying down of the primary spiral which is shown in this second plaque and which ended at *l*. All these threads consist of smooth, tough silk which is not sticky. From this point on, the spider uses the sticky threads which constitute the real snare. The details of putting in the first of the sticky threads vary greatly. The spider started at *m* (third plaque) and its course may be followed by the letters to *v*. From *v* she continued in a regular spiral until the primary spiral of smooth silk was reached. She then cut away the outer portion of the primary spiral so that she might have more room for the snare. This process of cutting away the primary spiral and putting in the sticky spiral is shown in the fourth plaque about half finished. The last plaque shows the completed web with nearly all of the primary spiral removed.

Besides the calamistrum, which is proper to the Cribrellates, spiders possess organs situated at the end of the legs which are employed to grasp and to weave the thread. To begin with there are two toothed claws to which there is sometimes added a simpler accessory claw. Besides these organs one finds in good spinners bundles of pectinate hairs and, furthermore, a special hairy covering which is likewise employed in weaving. . . .

The Cocoons.—Ordinarily the cocoons of spiders consist of a simple envelope; this envelope, which is reduced to a few threads in the Mygalas of the genus *Ctenize*, becomes thick in the Epeiras but remains loose and flocculent, while in the *Drassus* it is so compact that the separate threads can no longer be distinguished.

The structure is often more complex; in the majority of the *Thomisas* and in the *Lycosas* the cocoon has two valves, lens-shaped in the former, and nearly spherical in the second. That of our beautiful *Argiope Bruennichi* is a double walled balloon which is truncated and fringed at one of its ends; its internal envelop is a sort of cylinder provided with a lid which lifts at the moment when the young appear; it is attached by a loose tuft to the external papyraceous wall which tears in the sunshine when the offspring is ready to come forth. This tuft is often accompanied by various débris in the double walled cocoon of our *Tegenaria*. Sometimes the cocoon is suspended by a pedicle as in the case of the *Agraeca brunnea* in which it is in the form of a graceful silken amphora covered with a layer of tempered earth; it is separated by a diaphragm into two stories, the upper being occupied by the eggs while the lower receives the young after they are hatched and before they leave the cocoon.

Each species has its own architectural method which varies with the character of the structure. The large *Lycosa* of Narbonne studied by Fabre, builds its cocoon in the open air outside the burrow which it inhabits. It first spreads a coarse net upon the ground, then in the center of this it weaves a disk of superb white silk thickened at the edges. The eggs are dposited all at the same time in the central depression, forming a projecting globe which the little creature covers with threads. It then separates by means of its legs this disk from the network beneath it and folds it back upon the globe, thus producing a sort of equatorial ridge which does not adhere very closely. When it has become free the rounded cocoon is about as big as an average cherry, the upper end from which the young issue being thinner than the lower part.

As soon as this work is finished the Lycosa attaches her cocoon to her spinnerets until the day when it opens and the young ones emerge, after which she carries her offspring on her back. All the *Lycosiidae* attach their cocoon in the same manner while the *Pholquas* the *Pisouras* and *Dolomedas* of our own land hold it against the breast attached to the venomous hooks called the *chelicerae*.

This method of protection which is very troublesome for the animal and none too good for the mass of eggs is ordinarily replaced by the *incubating chamber*. Among the *Bisauras*, however, the second method merely follows suit upon the first; after having carried the cocoon around for awhile these wandering spiders weave a huge bell-shaped structure where they deposit them and where they stay on guard after the young appear, remaining for some little time afterwards. Other wandering spiders make use of the second method at the beginning; thus the *Thomisiidae* of the genus *Misumena* establish a hammock where they watch over their mass of eggs and in the family of the *Clubioniidae* the *Micrommata* weave a large incubating chamber of silky tissue, constructing it upon bushes or trees.

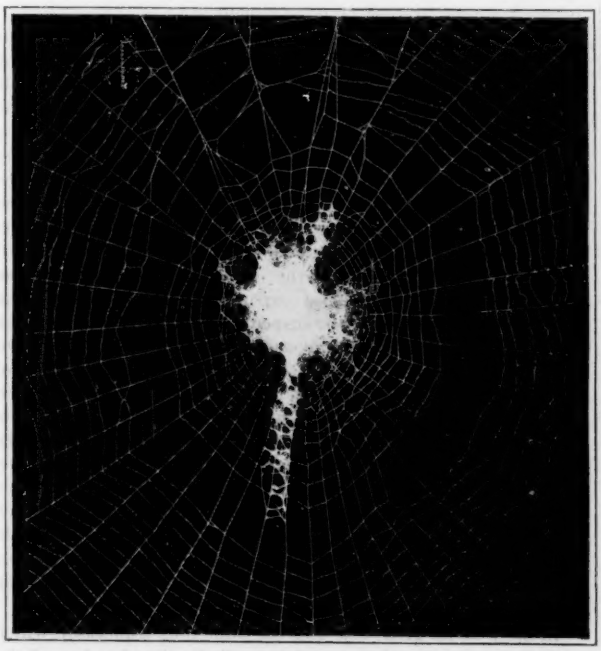
There is reason to believe with Pocock (1895) that the spider "by a slight modification of its intelligence has been led to extend to itself the protection" which it afforded first to its eggs and that in this manner the incubating chamber has become a permanent abode. Furthermore, this transformation is effected according to two divergent manners, whose point of departure is found in the family of the *Drassiidae;* some of these spiders confine themselves to the construction of an incubating chamber, but Simon (1892) notes that others such as the *Drassodus lapidosus* make of this chamber "a large, residential shell, where they pair with each other and stand guard over their eggs," while the species of "the group of *D. troglodytes* do not construct the shell but either stand guard over their cocoon on the open ground or else dig a sort of little burrow which they make use of as their retreat." These are the two sorts of industries proper to the tribe of spiders: the *burrow* which serves at once as a shelter and as an incubating chamber; and the *residential shell* which extends into a web but which does not always continue to serve to protect the eggs.

The Burrow.—The earth digging industry has been developed independently in two groups which differ greatly from each other: the *Lycosas* and the *Avicularüidae* or *Mygalas*. In the first we can observe all the stages between an existence which is frankly wandering and that of an almost entirely sedentary life: "The small species of the genus *Lycosa*," writes Simon (1897), "found in meadows and woods pursue their prey by the chase; some of them (*L. nemoralie* . . .) build no retreat, others take refuge at the egg-laying period beneath a stone and surround themselves with a little rampart of earth (*L. pulverulenta* . . .), while still others (*L. fabrilis*) dig a shallow shelter which is often garnished with threads; those which live upon shifting sand (*L. perita* . . .) adorn their dwelling with a little silky sheath which is very slack and is agglutinated . . . the large species dig a burrow which is often quite deep and is vertical as a rule . . . ; its yawning orifice is surmounted by a little circular or semi-circular wall which has been compared to a bastion." In the group of the *Tarentula lycosas*, at least, the digging habit although definitely instinctive develops only with age: Fabre has proved, in fact, that the young of *Lycosa Narbomnensis* are wandering spiders during the greater part of their first year and do not dig a shelter till the coming of autumn; he has observed also that the animal establishes this retreat little by little, that it never abandons it, and that is it incapable of making a second one when dislodged from the first, in which case it becomes wandering unless provided with another. This shelter is not built of masonry but is covered with a little silk, at least in its upper portion.

The *Avicularüidae* and the closely related *Atypus* possess in a very high degree, the skill of the miner they also know how to construct masonry, for before weaving for their retreat an envelop of silk they rough-coat it and make it impermeable by means of a mortar made of earth and saliva. The galleries of these *Arachniidae* differ greatly according to the species, being sometimes in the form of simple pits more or less inclined as in the mason *Migala* (*Nemesia comentaria*), sometimes expanded into a pocket in the lower portion as in the *Atypus Abboti*, and sometimes having a lateral gallery of refuge as in the *Nemesia Meridionalis*, the *N. badia* modifies its burrow in the autumn, making a second orifice in it. This seasonal habit becomes a custom in the *Stothis astuta* which, according to Simon (1889), digs an underground gallery in the form of an arc in the shifting soil. Many exotic species make their galleries in wood, perforating the bark for this purpose.

A young English observer, Moggridge, devoted the last days of his too brief existence to the study in the vicinity of Nice of the manner in which our *Mygalas* establish their retreat. "The legs" he says (1873), "are not employed in the digging and the palps are but little used; the principal instruments employed are the *Chelicerae* with their hooks. As soon as a little earth has been detached and collected the spider comes to the edge of the hole and there deposits a full mouthful of material, spreading its *chelicerae* apart and shaking them up and down so as to let fall the ball of earth which it has held between the hooks and the buccal organs." Better to perform their work certain species have a sort of rake upon the basal joint of the *chelicerae* near the hook; others, according to Simon, use the hind legs to push off the earthy particles detached by the *chelicerae*. The earth dwelling *Lycosas* also work with the *chelicerae* but they always lack a rake, and according to Fabre they hold the pellet of earth which they are carrying with the palp.

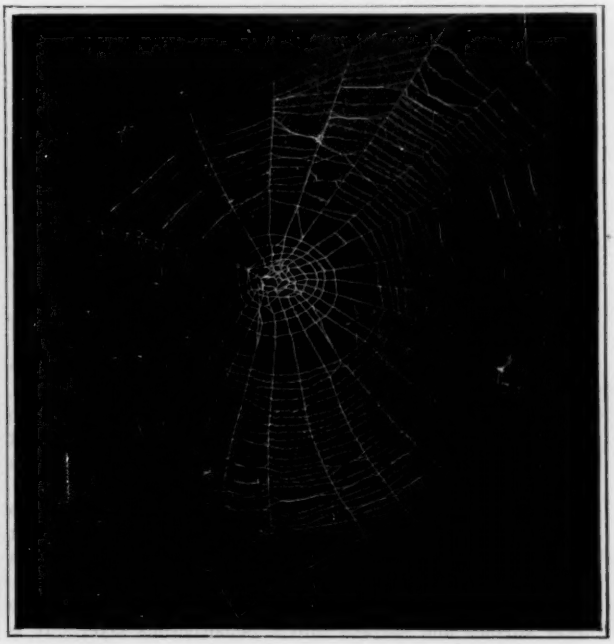
Fabre has likewise studied the manner in which the *Lycosa* of Narbonne builds the bastion which surrounds the opening of its burrow. It forms it "of little pebbles, bits of wood, scraps of dry leaves, etc., the whole dexterously interlaced and cemented with the silk." And again it is the *chelicerae* which are employed. Many *Lycosas*, especially among the American species perform similar labors. McCook reports (1889) that the *Lycosa arenicola* builds a bastion in the form of a chimney with small bits of straw or wood and that . . . at the base of this edifice it builds a little wall of grains of quartz. More skilful still, the *L. Carolinenses* executes a neat bit of basket work; it curves, interlaces and fastens pine needles, so as to form a sort of bastion in the shape of a bird's nest upside down. Sometimes the bastion is a mere prolongation of the silky inner tube, as in the *L. tigrina* in which it spreads into a cone and inclines towards the ground,



Courtesy Amer. Mus. Nat. Hist.

WEB OF THE METARGIOPE TRIFASCIATA

This and its larger relative Miranda aurantia are among the most conspicuous of the orb-web spiders.

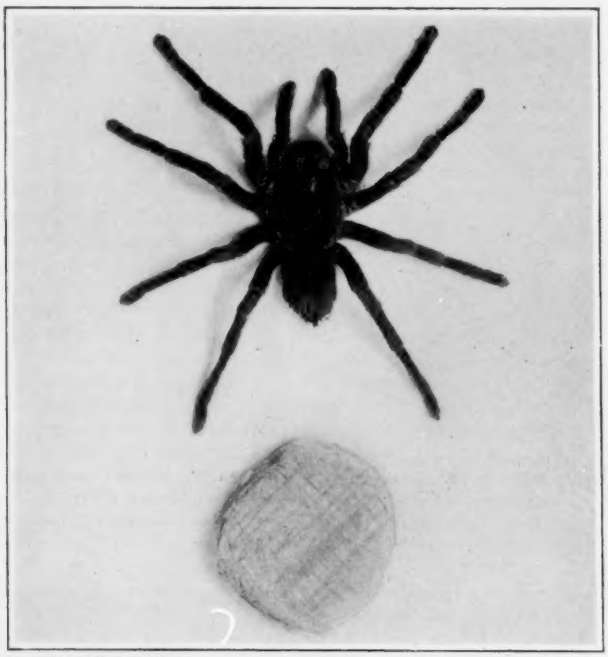


WEB OF THE ARANEA TRIFOLIUM

A signal line runs from center of web to the tent which it makes of leaves and silk some distance off.

and in the *Atypus Abboti* in which it is a long tube fastened to the trunk of a tree. . . . Simon also mentions an Algerian *Mygala* (*Leptopelma elongata*) in which the upright bastion has the form of a spreading funnel. . . .

The bastion is an observation post but above all it is a protective edifice. Fabre observed that the Narbonne *Lycosa* frequently closes the orifice of its nest by a silken ceiling, which it perforates and throws to one side when it wishes to make its exit; he supposes that the habit of building a bastion may be derived from this. However this may be, Mary Treat (1880), has shows that such edifices may afford effective protection to the spider. Like the other earth dwelling *Lycosas* the *L. tigrina* razes its bastion in the autumn and closes its shelter with various materials; it also closes it at certain periods during the summer but at this time it leaves the edifice untouched, covering it with leaves, moss, or grass, so as to



Courtesy Amer. Mus. Nat. Hist.

BIRD-SPIDER AND ITS EGG SACK

entirely hide it. This is at the moulting season, and later when it is about to spin its cocoon the spider also shuts itself in in this manner, but this is also in the midst of August at which time its activities should be very great. However it is in the month of August that the *Elis 4 notata*, the bitter enemy of the *Lycosa*, sets forth upon the chase, and it is probably to protect itself against the attacks of this predatory wasp that the spider closes its dwelling. The young *Lycosas*, which are scorned by the wasp, never take this precaution; as for the adults they seem to foresee some return to the attack, for even after the season of the *Elis* has passed, when they have opened their bastion, they leave attached to the edge of it a bit of foliage or the like which they make use of as a swing door, which they pull shut after them when danger threatens.

This brings us to the operculum or lid which serves to close the burrow of some *Lycosas* and of most *Mygalas*. That of the cunicular *Lycosa* of Algeria protects a retreat which lacks a bastion; it is simply a disk of earth whose solid particles are held in place by a silky network, which covers the lower surface and spreads into a homogeneous layer. It is kept in place by a few threads which do not make an elastic hinge so that it is found cast aside when the spider makes its exit.

The opercula of the *Mygalas* exhibit a more perfect form of industry and their nests belong to two types which have been called by Moggridge wafer-nests and cork-nests. The lids of the former are thin and rest upon the orifice without penetrating it and are mainly silky, but are often encrusted with earth; when they are rigid in character the hinge is remarkable for its great elasticity. The simple burrow of our *Nemesia Simoni* is closed by a soft operculum. The lids of cork nests always penetrate the orifice fitting it exactly like the stopper in a bottle; they are made of alternate layers of earth and silk, have a more or less perfect hinge, and have a thick covering of silk on the underside; they are found in many species in the neighborhood of the Mediterranean Sea. . . . The simple burrow of the *Nemesia Eleonora* observed by Moggridge has two lids, the outer one of the wafer type and the inner one of the cork type; the same thing is seen in the bifurcated burrow of the *Nemesia Meridionalis* in which the operculum is immediately in front of the bifurcation. The bifurcated burrow of a Venezuelan *Mygala* (*Rhytidicolus structor*) . . . has three lids all of the cork type, one outside, the second have the middle of the principal gallery, and the third at the orifice where the latter opens into the bifurcation.

The layer of silk which lines the inside surface of the opercular of the cork type sometimes has a marginal series of holes which enable the spider to hold the door shut by inserting its claws. Moggridge observed that when one knocks upon the lid of the mason *Mygala* the spider sometimes remains perfectly quiet but sometimes on the other hand leaves the bottom of its retreat in order to hold the door tight shut. When the latter is forcibly opened one sees the *Mygala* with all its claws hooked into the lower cushion of silk. . . . The spider thus holds itself across the pasage way with its back downwards and its head opposite to the hinge. This instinctive act is a reflex action, but it was without doubt occasioned by intelligence when it originated. The inside operculum of the *N. meridionalis* serves to close the lateral branch when it is drawn inside and the principal gallery when it is thrust outward. The *R. structor* undoubtedly performs two similar maneuvers, for its two opercula at the extremities open from within outward, while that in the middle opens in the opposite direction. It is evident that the instinct of these spiders is as remarkable as their industry and must have undergone a long process of development.

The Web.—As Pocock points out, while the operculum of the earth dwelling species is the result of a need of protection the web of the aerial species was evolved by the need of obtaining prey. It is at first a simple shell for habitation and the deposit of the eggs as is seen in the Saltiques but this shell sometimes assumes quite large dimensions and becomes an observation post whence the spider departs to follow the chase. An example of this is seen in the "Clotho" (*Uroctia Durandi*) studied by Fabre; this southern species constructs a reversed cupola underneath stones, almost as large as half a mandarine. "The edge of the cupola radiates into a dozen angular prolongations whose expanded point is attached to the stone. Between these suspension cables there open an equal number of spacious inverted arcades. A flattened roof stretched between the cables of attachment closes the top of the dwelling . . . all the arcades of the edge open underneath the roof" save for one which is similar to the others except that it is in the form of a two-leaved door which the spider can open or close. It is through this door that it departs for its nocturnal chase, but it is in the interior of the chamber that it plants its cocoons, five or six in number which it stands guard over from October to the following June without taking food. When the young ones have taken their departure the mother abandons this dwelling and goes elsewhere to build another.

In spite of its great size and the numerous *trabesulae* which attach its dome to the ground beneath it, the chamber of the Clotho is not employed to capture its prey. . . . Our little *Chiracanthium Carnifex* builds upon the panicles of oats or

in leaves an ovoid shell about the size of a pigeon's egg; this shell is thick, opaque, very smooth inside, open beneath and connected with the adjacent plant organs by threads; the spider remains ambushed within in order to seize the insects which frequent the stalks of grain or which become entangled in its threads. Thus the dwelling is not only a hunting post but to some extent an instrument for the purpose of capture; it also serves as an incubating chamber and the spider closes it up to stand guard over the cocoon and await the birth of its offspring.

In the family of the *Theridiidae* a true web makes its appearance—quite irregular to be sure and with very large meshes comparable to a certain extent to the "fixator" network of the Clothos and of the *Chiracanthium* but much more extensive and well fitted to be used as a trap. In our *Theridium Riparium* it extends in every direction around the chamber, which it helps to hold firm. This chamber is conical, open beneath, and covered on the outside with small stones or earthy or vegetable débris which make it resemble the tube of the *Phrygana* or of the *Psyche*. This *Theridium* which is sedentary like the *Chiracanthium* captures its prey by entangling them in the network; and when the period of egg laying arrives it fastens its little globular cocoon inside the point of the cone. Some of the *Theridiiae* content themselves with constructing an incubating shelter in the midst of their web and some of them, such as the *Theridula*, attach the cocoon to a spinneret like the *Lycosas*. The latter leads us to the industry of the *Pholqua* which construct a web similar to that of the *Theridiiae* but which remains lying back downward upon this web carrying its cocoon upon its breast attached to the *chelicera*.

Being a network annexed to the dwelling chamber the web is perfected in two different manners—*a sheet of close-woven tissue* and the *orbicular network*.

The first of these methods is exhibited in two forms of the same family—the *Tegenaria* and the *Agalenas*. In both of these the chamber of inhabitation which is also a look-out post has the form of a funnel with a double orifice; the circumference is large and is continued by a sheet of close woven tissue in which end the threads of the network are employed for capturing the prey. When the time for laying her eggs arrives the spider leaves the web and plants her silky cocoon somewhere in the neighborhood. Our *Agalena labyrinthica*, which establishes her web upon the grass, also constructs her snow-white chamber with two exits, where she perishes in the autumn in the midst of her watch over the mass of eggs from which the young will not emerge until the spring. The large spider found in cellars and on walls (*Tegenaria parietina*) also stands watch over her eggs in an incubator hammock, but the other *Tegenaria* content themselves with placing their cocoons and afterwards return to their webs. Among these their predatory habits predominate over the care of their progeny; we shall find the same thing to be true in those species in which the orb-web exhibits its most perfect type.

The various stages of the development of the orb-web may be observed in the large family of the *Argiopiidae*. The *Linyphia* leave an irregular network like that of the *Theridions*, but this network supports a flat web in the *L. Costate* and two dome-shaped webs in the *L. Communis* in which we see an indistinct orb arrangement make its appearance. There are likewise two superposed webs in the *Cyrtophora Basilica* studied by McCook (1889), but while the lower web is flat the upper one is a dome with an evident orbicular arrangement. Like the preceding ones this species remains in the structure without a residence shell and places its eggs there, the latter being connected in the form of a string of cocoons.

In the *Theridiosoma gennosum* (*Epira rediosa* of McCook) the web is stretched vertically, being sustained by radii which are fused together towards the center and without a spiral thread except at the periphery where the rudiments of one may be seen. The spider does not remain within the web, but stays upon a taut guide line which gives the web the appearance of a cone. The vertical web of the *Zilla* is an incompletely regular orb in which the radii and the helix are interrupted in a triangular segment traversed by the guide line; the latter leads to a dwelling shell in the form of a bell or thimble. The large tropical spiders of the genus *Bephila* and our own *Argiope* do not stretch a guide line; the former remain in a close woven network which occupies a hollow at the upper edge of their web and the second stay at the very center of the structure, which is sustained by one or two zig-zag radii, the *Stabilimentum*, formed by a tuft of interlaced threads. In both, moreover, the web is almost vertical and forms a perfect orb as it does also in our *Araneus* or *Epeira* which also have a guide line at the end of which is a dwelling shell which serves them for a retreat and an ambush during the day. In these latter forms the cocoon is rarely placed within the web being generally found in the vicinity and receiving no care. Here again the original maternal instinct which forms the point of departure for arachnean industry is dominated by the predatory habits.

Courtesy Amer Mus. Nat. Hist.

AN ENORMOUS TROPICAL SPIDER WITH A SPREAD OF 7 INCHES AND BODY 2 11/16 INCHES LONG (HORNOEMMA SP.)

The most difficult but not the most delicate work in the making of an orb-web is the establishment of the suspending cable which stretches between two points at a distance from each other and supports the whole structure. Sometimes the spider fastens its thread at one of these points and then repairs to the other where it stretches and fastens the cord which has issued from its spinnerets during the course of its journey. But this process is not applicable over all sorts of *terrain* and is even practically impossible when the two points are separated by a stream of water or by any other insurpassable obstacle. In this case the spider stations itself or suspends itself at one of the points . . . and emits a thread which is carried by the wind until it attaches itself at another elevated point. According to Fabre the process may differ somewhat, however: the spider may suspend herself but soon thereafter reascends by her thread; the latter then forms a loop which is stretched out and fastened by the wind as in the preceding cases. In any case the spider knows quite well when the attachment has occurred. She then stretches her cable, and runs back and forth across it several times in

order to multiply the number of threads and thus render the cable more firm. The next thing is to establish another side to the framework: the spider suspends herself again, then reascends by means of her thread, follows the cable to the opposite end, and then seeks a suitable point further down where she stretches and fastens the thread emitted in the course of the journey.

In the same manner, or by simply walking from one point to another a diagonal thread is established which serves as the first radius of the web. Upon this diagonal line a point is chosen to be the center of the structure; the spider attaches a second radius at this point and then proceeds to walk to the framework where she fastens the other extremity, after which she returns in the opposite direction to stretch this thread and make of it a definite radius; the excess length is reserved at the center to form a cushion. Now at one side and now at the other, in order to render the structure more stable, the spider attaches new radii by the aid of those already established. When finished the radii are spaced at equal distances; they vary in number according to the species; Fabre counted twenty-one in the angular *Epeira* and thirty-two in the fasciated *Argiope*.

Resting upon the cushion the spider now revolves repeatedly about her own axis, attaching to the radii a central helix whose inter-radiary elements are straight lines. Then she advances a little farther and begins to establish a second similar helix which extends to the framework. This second helix is permanent in the *Nephilae* and temporary in the *Argiopae*, the *Epeira* and most other forms. Since it consists of cylindrical threads it is not very suitable for purposes of capture. Consequently as soon as it has carried it to the framework the animal returns along this helix, placing between its spirals a new helix whose elements are composed of threads bearing sticky globules. This helix constitutes a marvelously effective trap. In establishing it the spider takes for a support and scaffolding the auxiliary helix; but as the work proceeds the latter is destroyed except among the *Nephilae*, in which it is retained to give more solidity to the structure.

Upon arriving at the narrow open space which separates the auxiliary helix from the small central helix, the spider returns to the cushion which has now become useless and reduces it to a compact mass which she proceeds to swallow and digest to provide new threads. At this place the *Eperia* weaves a loose network while the *Argiope* makes a sort of shield of microscopic threads which serves as a sort of support for the look-out post; in the latter the *stabilimentum* is a mere prolongation of the shield and exhibits the same structure.

Spiders that have a cribellum replace the threads that bear globules by calamistral threads as seen in the *Uloboras* which make an orb-web which is similar to that of the *Argiope* but is extended horizontally.

The orb-webs and especially those of the *Epeira* represent the most perfect type. Pocock has shown how their radial structure indicates to the animal the very point at which they are disturbed and how the arrangement of the spirals sustains them though leaving them almost invisible, without increasing their weight to such a point as to involve breaking by means of rain; furthermore, the elements of the helix cross the rays at such an angle that they give to the structure a maximum of solidity with a minimum number of threads, so that in constructing these orbs "an *Epeira* economizes both time and silk and makes her net as resistant as need be while as delicate and nearly invisible as possible."

Psychology of Spiders.—In order to arrive at such a degree of perfection and to be able to adapt themselves so well to their industrial needs our *Epeiras* must have gradually developed through various stages from the epoch when their ancestors contented themselves with weaving a simple cocoon. Among them, as among the spiders which weave sheets of web and among the earth dwelling species the comparative method of study has enabled us to reconstruct in a measure the series of these stages which has led us to the present form of the industry. . . . But it must be admitted that our knowledge of arachnean psychology still leaves us in ignorance as to the manner in which such a great degree of progress has been accomplished.

It is not always easy to decide between the parts played by intelligence and by instinct, but apparently the former is low in degree and dominated by a strict automatism. . . . The *Nemosculus Laurae* establishes in a vertical position near her orb-web the inverted cone which serves as her retreat; this is constructed by starting with the periphery of the orifice but "from the very beginning the threads which hold the orifice open are placed in position and a few temporary threads hold the upper portions of this ring;" is it possible to ascribe to pure automatism or to mere reflex action so judicious a bit of architectural scaffolding? Undoubtedly the psychology of spiders offers a vast field for observation and experiment.

Nevertheless, thus far, research has demonstrated but little intelligence among spiders. Fabre reports that the *Nephila* of Madagascar, nightly renews the viscid threads of half its web and regularly alternates this destruction and remaking of one-half and the other. But if the new made half be injured or destroyed the spider pays no attention but automatically destroys and remakes the part remaining intact. Fabre

Courtesy Amer. Mus. Nat. Hist.
NEST OF THE TRAP-DOOR SPIDER

has noted that our native species are incapable of repairing their web when it is injured; he has seen the angular *Epeira* collect the fragments and swallow them, starting from the beginning to make a new one; he has also seen the same species reunite by a simple thread the two halves of a web which had been split along the diameter or else remain motionless in the center of the network whose helix had been destroyed while the radii remained intact. . . .

Our *C. carnifex* seems to take better care of its dwelling. "If the wall is torn it repairs it without leaving it; if the nest be cut into fragments it unites these with a remarkable patience." But we are here concerned with maternal cares and these are nearly always automatic among spiders. . . . Warburton has observed that when our labyrinth *Agalena* has finished constructing its complicated incubating chamber it remains there even if the eggs are removed ;and Fabre states that Thomisa readily accepts the nest and cocoon of another member of the same species, while the Narbonne *Lycosa* glues to its spinnerets as if it were a pouch of eggs, a ball of cork, paper or thread, and finally, that the same spider will readily accept other offspring when deprived of her own. The Peckhams even report that a similar spider several times accepted a ball of lead three times as heavy as her pouch of eggs, but covered with the envelop of the latter. Fabre has interpreted these curious phenomena by saying of his Thomisa "Provided it has a piece of satin under its legs does not perceive its mistake." . . . But it may be observed in this connection that many mammals and birds can be similarly

deceived . . . does not one see hens lavish their maternal warmth upon imitations of plaster or stone? In short our spiders are attached to their cocoon or their nest and not to their progeny. This explains the labor of the *Chiracanthium in repairing its injured shell.* Lécaillon has noted that this species is more attached to its nest than any other, that it recognizes the nest after an absence of a week, and spares no pains in the effort to re-enter it, and that it defends it with fury when one tries to remove it. . . .

Some authorities have seen a proof of intelligence in the behavior of certain *Mygalas* which hide their operculum by coverign it with bits of vegetation. It is possible that this habit originated in an intelligent act, but it has certainly become entirely mechanical and is even of disadvantage to the animal at times. Moggridge says: "I have removed a little clod of mossy earth about three inches square and two inches thick from the surface in the terrain where there was the orifice of the burrow and the cork-lid of the *Nemesia cementaria.* Six days later I found a new operculum upon which the *Mygala* had planted moss found nearby. But this actually served to attract attention instead of hiding the burrow since it was in the midst of the little area of brown earth which I had left when removing the clod."

Does all this mean that spiders are entirely lacking in intellect? Not at all. They prove that they possess memory by the recognition of their nests; many examples show that they are capable of learning . . . , and they necessarily display a certain degree of discernment when they establish the bases of their shell or nest. And it is by making use of these faculties that they have been able to display plasticity in their habits and undergo an evolution in their industries. At the present time they are doubtless quite as capable of evolution as in former times, but this tendency escapes our notice because of the automatism which dominates it. We are particularly struck by the extraordinary rôle played by touch in their automatic manifestations. Spiders nearly always perform their labors at night and it is merely by touch that they are able to recognize whether their cables are sufficiently taut, their radii properly spaced, and the spirals of the helix regularly placed. With their legs and their palps they search for contacts and measure distances and the sensitiveness of the spinnerets reveals to them the moment when their silken thread is properly attached. They seem to work as if blind, being largely guided by simple tactile reflexes.

Aeronautic Spiders.—Young spiders and in some cases adults also owe their faculty of crossing space like aeronautics to a peculiar form of tactile sensibility. This curious phenomenon was pointed out in 1670 by Martin Lister and has since been the subject of numerous observations including those of Darwin. During the cruise of "The Beagle" when the ship was sixty miles from land in the mouth of the La Plata, he saw the space around him filled with floculent webs. "A large number of little spiders about one-tenth of an inch long were hooked to the webs. I suppose there were thousands surrounding the ship. When the little spider came in contact with the rigging it was always hanging to a single thread and not to the flocculent mass. The latter seems to be produced by simple threads. These spiders were of a single species, but of both sexes, with their young. . . . While I examined some of them hanging from their single thread it repeatedly happened that the lightest breath of wind carried the spider out of sight in a horizontal direction."

Three weeks later Darwin saw members of the same species climb upon a projection, lift the abdomen, emit threads, and bringing their legs close together sail rapidly away. In his opinion it was the hot air rising from the ground which carried away the little creatures suspended from their threads.

Not a line of this account but gives an exact idea of the manner in which the spiders manage their aeronautic travels. The sole point which remains somewhat obscure is the method employed by the animal in emitting its thread and suspending itself therefrom. This differs in different species. According to McCook the wandering spiders . . . climb up to an elevated point, place their heads in the direction of the breeze, lift the abdomen, and spreading the fusules and spinnerets apart, emit a quantity of fine threads which follow the direction of the wind. Arched upon its legs the animal at first resists this force, which tends to lift it, and then when the threads are long enough it allows itself to be carried away with its back downwards and its legs pressed against the body. It can also climb along this floating rigging which it shortens and gathers into a ball against its ventral surface or which it elongates by the functioning of its spinnerets. . . .

The method seems to differ in the case of the orb-web spiders, in which it much resembles that which preludes the establishment of the suspending cable. Fastened by one end and the other continuously with the spinnerets the ropes of the aeronauts take the form of a loop under the influence of the current of air which carries them away and stretches them; and when their ascensional force is sufficiently great they are severed near the point of attachment. . . . Details seem to vary in different species or individuals. According to McCook the spider suspends itself by a long thread which breaks under the action of the wind; according to Fabre the fasciated *Argiope* suspends itself repeatedly, reascending to make a collection of threads. . . . "Gently lifted by the ascending currents which rise from the ground heated by the sun, this thread rises, floate, undulates and strains at its point of attachment. Finally it breaks and disappears in the distance bearing with it the creature that spun it." . . .

* * * * *

However the manner may differ spiders behave like aeronauts making use of a kite: they require a current of air to carry away the thread which suspends them and this current always results from differences of temperature in the different strata of the atmosphere. In Favier's experiments this current was produced by the temperature of the observer's body and when he increased his distance the little parachute descended. Consequently the flights of spiders may occur only on fine, warm days when there is a gentle breeze, or when the superheated ground produces an ascending current of air. When favorable weather coincides with an abundant hatching of young spiders, as happens especially along towards autumn, the ropes of our aeronauts float in large numbers over plants and in the atmosphere where they compose those silky ribbons commonly known as the *threads of the virgin.* Sometimes individuals of large size also fly in this manner: "The largest orb-web spider which I have ever seen floating in the air," says McCook, "was a big *Epeira domiciliorum* nearly a quarter of an inch long. After having floated above a field it crossed a road and attached itself to the top of a young tree. It was never more than 20 feet high, but I had some trouble in following its flight with my eye." But young spiders are able to reach a much greater height, for the same biologist tells us that he found *Epeiras* spinning their threads at the summit of the dome of St. Peter's.

Most spiders, but not all, are capable of this sort of aerostation. . . . This faculty is eminently favorable to the survival of the species, since our *Arachnidae* are born in groups in a cocoon and are disseminated in space like the winged seeds of plants, thus more readily finding favorable places of existence. McCook explains in this manner the vast area of distribution of a large tropical spider, the *Heteropoda venatorie* which is found without perceptible variation in all those continental regions where the trade winds blow.

In fine, the flight of spiders is a phenomenon in which the tactile sensibility of the spinnerets plays a great part, since this indicates to the animal the amount of ascensional force at its disposal; it involves a certain degree of discernment since the aeronaut can prolong its ascension or direct it towards the earth at pleasure by elongating its cable or by gathering the latter into more or less of a ball, but it is difficult to tell the precise degree to which these intelligent acts have assumed an automatic form in different species.

Science and National Progress

Edited by a Committee of the National Research Council

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FOOD AS A NATIONAL INTEREST

By Vernon Kellogg.

The National Research Council is a co-operative organization of the scientific men of America. It is established under the auspices of the National Academy of Sciences and its membership is largely composed of appointed representatives of the major scientific and technical societies of the country. Its purposes are the promotion of scientific research and of the application and dissemination of scientific knowledge for the benefit of the natioanl strength and well-being.

ABOUT a quarter-century ago the great Polish economist, Jean Bloch, declared in his famous book, "The Future of War": "That is the future of war, famine, not fighting." And while this epigram was revealed by the World War of 1914-1918 to be but a half-truth, as most other epigrams are, yet the element of real truth in it was abundantly proved. If the Allied and American military effort had not been successful in the fall of 1918, as it was, famine would have been successful in 1919 in ending the war. Even as it was famine played an important part in making the military victory possible at the time it occurred.

So insistent throughout the war was the food problem of all the nations engaged in fighting and, incidentally, of many nations not fighting, especially the European neutrals, that Food Ministries, Food Controllers and Food Commissions were established by all these harassed governments, and the governmental and popular attention to food matters was hardly less than that which was given to military matters.

In all these governmental efforts to administer food most economically and effectively for the sake of the national physical strength and spiritual morale—for starving is a great weakener of morale as well as of body—and in all the great private relief undertakings, the food administrators early found themselves face to face with the necessity of knowing as much as they could of the scientific basis of rational food use. And in trying to find out what this knowledge is, the various responsible administrators and their advisors soon discovered that this scientific knowledge is anything but complete: there are great gaps in the necessary knowledge and great differences of expert opinion about many matters which are a part of the alleged knowledge as far as it goes.

So serious was the need of bringing to bear on the situation all that science could contribute that even during the stress and rush of war the Allied governments and America united in forming an Inter-Allied Scientific Food Commission composed of leading physiological chemists and special food and nutrition experts from each country. This Commission met at different times in the spring of 1918 in Paris, Rome and London, again in Paris in October, 1918, again in Rome and Naples in December, 1919, and finally at Brussels in May, 1919. The results of the Commission's meetings are included in various reports which were handed promptly to the Food Ministries and other food-controlling authorities of the various countries represented on the Commission and much use of the findings and recommendations of the Scientific Commission were made by the authorities on whom fell the responsibility for the allocation of food quantities to the various Allied countries from the existent and obtainable supplies.

Among the interesting points taken up by the Commission were: First, the determination of the most desirable daily ration for the "average man" from the point of view of total calories necessary and the best relative proportions in this ration of proteins, fats and carbohydrates; second, the determination of the proper coefficients to apply to infants, children, and women and men doing different kinds of work, that is, no work, light work, heavy work, etc., so as to define their food needs in terms of those of the "average man"; and, third, the determination, on a basis of the varying make-up of the population of the different countries, what coefficient should be used for each country to express its total needs in terms of the "average man" ration.

As for the first point, it was agreed that a daily ration composed of a variety of foodstuffs, including meat and bread, providing 3,300 calories, or energy units, was proper for the "average man," and that this ration should include in its make-up at least 75 gr. of fats. It was agreed that in practically any mixed ration provided that would produce 3,300 calories a sufficient supply of protein matter would almost certainly be included, so no specific recommendation as to protein content was made. The same applies to the carbohydrate content.

As for the second point, the following coefficients were agreed on:

Age and Sex.	Coefficients of Conversion into the "average man."
0 to 6 years (both sexes)	.5
6 to 10 years (both sexes)	.7
10 to 14 years (both sexes)	.83
14 years and above (women)	.83
14 years and above (men)	1.00

As for the third point, the determination of the coefficients to be applied to the total population of the different countries taking into account the relative proportions in each population of men, women and children, the following were decided on:

United Kingdom	.835
France	.845
Italy	.826
United States	.84

That is to say if we take any one country, as England, for example, it is believed that an average 100 of the population equals from the food needs point of view 83.5 "average man."

Many other important problems were taken up, but most of them refer to conditions which only exist in times of war and hence are of less present interest. One, however, is of perennial interest. It is that of the most advantageous rate (extraction rate) of milling the various grains when it is desirable to have the available supplies of these grains go as far as possible in bread-making, *i. e.*, produce as many loaves of wholesome bread as possible. This is primarily a matter of special interest in times of grain shortage, but it also touches the moot question of "whole wheat" bread versus bread made from flour of lower extraction rate. It would obviously "stretch" the grain more if 100 per cent flour (containing all the "offals") could be used in times of grain shortage, but the Inter-Allied Committee of representative physiological chemists and nutrition experts decided that even in times of great shortage wheat could not advantageously be milled at an extraction rate higher than 85 per cent for use in making bread for the whole population. For certain individuals there is little doubt that a higher rate would not be disturbing; for others it is preferable to use even a lower

rate. For rye the recommended rate is 70 per cent, for barley, 65 per cent and for maize, 85 per cent.

At the Brussels meeting in May, 1919, which was the last held by the Commission, it was decided that as the war had passed and the Commission had been formed as a war organization it should dissolve itself. This was done by formal resolution, to which was attached an equally formal and positive recommendation that a permanent international scientific food commission should be established to take its place. And it was further decided to attempt to have such a committee function in some recognized affiliation, perhaps like that of the International Red Cross Societies, with the League of Nations. Nothing has been decided about this as yet, but it at least shows how convinced were the governments whose official delegates had represented them on this war food body that there is need of a continuing study of the science of food use in relation to its larger aspects, national and international.

In the meantime separate action has recently been taken by the National Research Council of this country to initiate and carry forward work on certain food and nutrition investigations which are of pressing importance. This action has resulted in the formation of a special Committee on Food and Nutrition of the Council's Division of Biology and Agriculture. The Committee is composed of fourteen members who represent the physiological chemists, the experts in both human and animal nutrition, and the home economics students of the country. The list of members is as follows:

Chairman of the Committee, and of the Sub-committee on Human Nutrition, J. R. Murlin, Professor of Physiology and Director of Department of Vital Economics, Univerity of Rochester; Chairman of the Sub-committee on Animal Nutrition, H. P. Armsby, Director of Institute of Animal Nutrition, Pennsylvania State College; Carl Alsberg, Chief, Bureau of Chemistry, Department of Agriculture; Isabel Bevier, Director of Department of Home Economics, University of Illinois; E. B. Forbes, Chief, Department of Nutrition, Ohio Agricultural Experiment Station; W. H. Jordan, Director, N. Y. Agricultural Experiment Station; Graham Lusk, Professor of Physiology, Cornell University Medical College; C. F. Langworthy, Chief of Office of Home Economics, Department of Agriculture; F. V. McCollum, Professor of Biochemistry, School of Public Health and Hygiene, Johns Hopkins University; L. B. Mendel, Professor of Physiological Chemistry, Yale University; R. A. Pearson, President of Iowa State Agricultural College; H. C. Sherman, Professor of Food Chemistry, Columbia University; A. E. Taylor, Rush Professor of Physiological Chemistry, University of Pennsylvania; and A. F. Woods, Botanist, President of Maryland State College of Agriculture.

The problems which have already been formulated by individual members and sub-committees of the Committee and to which it purposes to give immediate attention, include those of the comparative food values of meat and milk and of the conditions of the production of these foods in the United States together with the whole general problem of animal nutrition; the nutritional standards of infancy and adolescence, and other similarly large and important problems.

A subject to which the Committee is giving serious consideration is that of the establishment in this country of a National Institute or Laboratory of Human Nutrition. Each of the delegations to the Inter-Allied Scientific Food Commission is recommending to its government that a national laboratory for the study of the problem of human nutrition be established in its country. If this can be done and an International Scientific Food Commission can be established in connection with the League of Nations, which can correlate the work of the various national institutions, a great and most needed advance in food science can be made. Not only can advance be made in finding out more of the actual character of various food stuffs and the actual needs of human beings of different ages and sex existing under varying conditions of work and disease or abnormality, but advance can be made in knowing more exactly the national production and consumption and waste of food in different countries, and in planning for more economical international food exchanges and general relations. And such a series of national food laboratories or institutes could also help materially to educate the people of their various countries in wise and economical ways of food use.

THE CERAMIC INDUSTRIES.

THE National Research Council and the American Ceramic Society have formed a special committee on Ceramic Research in affiliation with the Division of Chemistry and Chemical Technology of the Council. This committee is composed of Albert V. Bleininger, of the Governmen Bureau of Standards, Chairman; Professor E. W. Washburn, of the University of Illinois, Secretary; Arthur L. Day, Second Vice-President of the Corning Glass Company; Robert B. Sosman, acting director of the Geo-Physical Laboratory of the Carnegie Institution at Washington; and Homer F. Staley, of the Bureau of Standards. The first efforts of the committee are being directed toward the establishment of a group of university research fellowships in ceramics whose holders are to devote themselves primarily to the investigation of fundamental scientific problems in the ceramic industries, rather than to the "works problems" which, though equally urgent in their need of solution, can be attacked more advantageously perhaps in the ceramic plants themselves, and, anyway, have back of them still unsolved scientific problems.

The committee has recently prepared a report which contains much matter of general interest as throwing light upon the present-day status of the ceramic industries.

These industries, which include brick and tile making, and general crockery and glass manufacture as well as that of ornamental potteries, although among the earliest ones developed by man, have been among the last of our great manufacturing industries to rise from the status of empirical art to that of applied science. This is doubtless in a great measure due to the fact that the industry, being older than the science, had necessarily to develop in a purely empirical fashion. The many rule-of-thumb methods and so-called trade secrets which are the inevitable accompaniments of a complex industry, representing the accumulated experience of many generations of workers, have, in the past, naturally bred a conservatism not favorable to new ideas and methods or to a ready appreciation of the value of scientific research or the advantages of scientific control over its materials, processes and products.

In sharp contrast to the painfully slow development of these ancient industries we have those exclusively modern industries, such as the synthetic dye industry whose foundation was made possible by the discoveries of modern science and whose industrial success and marvelously rapid growth is almost entirely the fruit of highly organized scientific research with methods of scientific control at every stage of its operations. An English scientist is authority for the statement that the capital, large though it has been, which the German dye firms have invested in scientific research, has been the best paying investment which the world has ever seen.

It is true that the synthetic dye industry had, from its inception, the highly developed and rapidly progressing science of organic chemistry as its foundation. that is, the industry was not forced to explore a wholly new domain of science in order to ascertain fundamental principles and accumulate the data needed for its development. For the greater part of this material it could rely upon the results of the research carried out in the laboratories of the universities of the world.

In the case of the ceramic industries the situation has been somewhat different. The chemistry of the compounds of sili-

con, particularly the silicates, has not by any means reached the stage of development attained by the chemistry of the compounds of carbon, and in fact nearly all that we know concerning the chemistry and physics of high temperatures, which play such a dominant rôle in all ceramic industries, represents an acquisition of comparatively recent date. It is doubtless for these reasons that ceramics, as a branch, or as a potential branch, of applied science, received no recognition in the universities of the country until within the last quarter of a century. With the recent development of methods of producing, controlling and measuring high temperatures in the laboratory, however, has come the possibility of creating a new domain of science, the chemistry and physics of high temperatures. It is this new domain which will prove of fundamental importance to the ceramic industries, and the rapid expansion of our knowledge in this field should be encouraged and promoted in every way possible.

The committee believes that the industries concerned ought not, and in their best interests cannot, leave this work to the unaided efforts of university, governmental and institutional laboratories.

Fundamental research in this field is expensive, difficult and slow. New methods, new apparatus and new materials frequently have to be invented and created before the actual attack on the problem itself can be begun. The problems presenting themselves for solution are almost innumerable and many more workers especially trained for research in this field must be produced.

In the endeavor to enlist the active coöperation of the ceramic industries in furthering research upon fundamental ceramic problems in university, governmental and institutional laboratories of the country, the committee is submitting for consideration by the indisturies a plan for the establishment of Research Fellowships in Ceramics, each fellowship to be supported by one or more producers or users of a ceramic product.

In submitting this proposal, it seems desirable, in the interests of clearness, to explain somewhat more fully the distinction which the committee makes between "works problems" and "fundamental scientific problems." This can perhaps best be accomplished with the aid of one or two examples.

Typical examples of works problems are: The discovery of remedies (a) for the appearance of "white wash" on the ware in a waste heat drier and for the pitting and corrosion of the framework and cars of the drier; (b) for the formation of "kiln white" on the ware, or the production of "off color"; (c) for "blistering," "spitting out," "shivering" and "crazing" of glazed ware; and (d) deterioration of burned clay products under certain conditions. With the discovery of a successful remedy for the trouble the "works problem" is solved, regardless of whether the real cause of the trouble is known or the method if action of the successful remedy understood.

The source of some of the difficulties listed above has in many cases been ascribed to the presence of sulphur in the raw materials, the water, or the fuel employed, and the "disease" has often been cured by the avoidance of materials containing more than a minimum (determined by experience) percentage of sulphur. The chemistry of what takes place and how the reactions and equilibria depend upon the temperature and the partial pressures of the SO_2 and SO_3 in the gases of the kiln are, however, but little understood and the possibilities, which, in a given case, may exist of avoiding the necessity of employing a more expensive low sulphur material have not been investigated. Such problems represent the scientific aspects of the larger problem of the general influence of the presence of sulphur in the manufacturing system.

Other problems of this type are met in the manufacture of optical glass, the determinations, for each variety of glass, of the maximum temperature which must be attained in the melting process, the temperature at which stirring must be begun, the rate and amplitude at which the stirrer should be driven, and the temperature at which the stirring operation should be completed. Associated with this "works problem" is the fundamental scientific problem of the measurement of the viscosity of molten glass and the determination of the laws which govern the dependence of this physical property upon temperature and composition. In the same way the relation between composition and temperature, on the one hand, and viscosity, surface tension, gas content and vapor pressure of the molten glass on the other is a fundamental scientific problem intimately associated with the works problems connected with the process of fining.

To cite one more example, the chemistry of the rate and equilibrium of the reaction between aluminium silicate(or, more accurately, the aluminium silicates) and water, is a fundamental scientific problem at the root of works problems arising in the burning of clay wares (especially during the "water smoking" operation), in the rate of disintegration of the burned ware if afterwards subjected to high temperature and humidity, and in one of the common processes employed in measuring rate of vitrification.

Most "works problems" have behind them unsolved scientific problems. When the scientific problems have been solved there usually still remains a "works problem" for it is seldom indeed that the data of the laboratory can be immediately transferred to the works without further experimentation. The "works problem" which remains after the scientific questions at the root of it have been solved, however, often presents quite a different aspect from that which it presented at first.

IDENTIFICATION OF FUR.

WE are all familiar with the existing practice of clipping, plucking, dyeing, and otherwise changing the appearance of lower class fuds to make them appear and sell for the more desirable varieties. The furs of animals whose habitat is in the warmer countries is not so durable, does not form as good leather, and is less supple than the furs from the animals living in colder climates, so that for some time there has been a desire for methods by which furs could be identified, even after going through elaborate processes.

Dr. L. A. Hausman of Cornell University gives a popular account of his researches in the SCIENTIFIC AMERICAN MONTHLY, Vol. 1, No. 1, January, 1920. By the use of the microscope and micro-chemical methods Dr. Hausman has found that there are characteristics of most mammalian hair which can be used as a key to identification. The characteristics of most importance are the scales of the cuticle, considering their shape and arrangement on the hair; the diameter of the hair and of the medulla; and the disposition of the pigment granules. A variety of methods is required to emphasize these characteristics. Staining methods, treatment with various reagents, extraction with alcohol and ether to remove interfering natural oils and other technique has been developed by Dr. Hausman.

It may be of interest to note the relative durability of the different types of commercial furs and since experience has shown that the fur of the sea otter is the most durable, that is taken as 100 in the following scale: beaver, 90; bear, 94; chinchilla, 15; ermine, 25; fox, natural, 40; fox, dyed, 20-25; goat, 15; hare, 05; kolinsky, 25; leopard, 75; lynx, 25; marten (skunk), 70; mink, natural, 70; mink, dyed, 35; mole, 07; muskrat, 45; nutria (coypurat), plucked, 25; otter, sea, 100; otter, inland, 100; oppossum, 37; rabbit, 05; raccoon, natural, 65; raccoon, dyed, 50; sable, 60; seal, hair, 80; seal, fur, 80; squirrel, gray, 20-25; wolf, 50; wolverine, 100.

The examination for identity is usually made upon the under or fur hair, and not upon the outer protective hair of the skin. It is interesting to note the effect of dyeing upon the wearing qualities of the various furs. This work makes it possible to take another step toward informing the purchaser as to the real character of the merchandise in which he is invited to invest.

Survey of Progress in Mechanical Engineering

Prepared Under the Auspices of the American Society of Mechanical Engineers

AN IMPROVED WORM GEAR.

In a description of a worm gear developed by a British concern, it is stated that in a certified test made at the National Physical Laboratory, Teddington, England, an efficiency of over 97 per cent was secured.

The illustrations (Fig. 1) show the details of the character and area of contact in the new F. J. gears. The view on the left shows the worm in such a position that the drive is taken by the three threads, *A*, *B*, and *C*, while that on the right shows the worm in a different position, having been rotated through an angle of 45 degrees, with the result that the two threads *A* and *B* are in simultaneous contact with the worm wheel. The area in dotted outline across the teeth of the worm marks the zone of contact between the gears when the worm is rotated in the direction indicated in the end view. The intersections of the worm threads and the zone give the

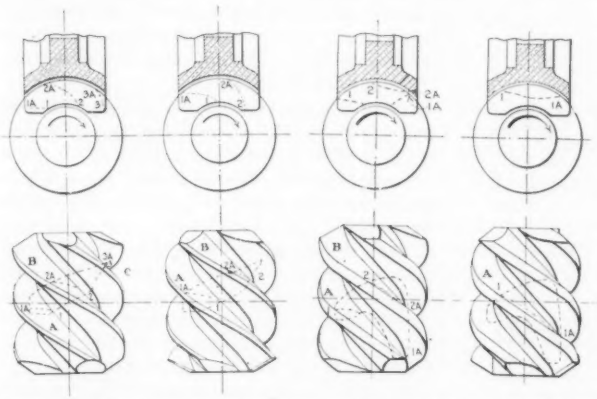

FIG. 1. ZONE OF CONTACT BETWEEN THE F. J. WORM AND WHEEL

FIG. 2. ZONE OF CONTACT BETWEEN THE ORDINARY WORM AND WHEEL

lines of contact between the worm and wheel teeth, and at no point outside this zone is there any contact between worm and wheel. It is this contour of the zone of contact that was arrived at by the mathematical calculation previously referred to, and which was submitted to Faraday House.

In the left-hand view, the actual contact between the worm thread *A* and the wheel is marked by the dotted line 1-1*A*, that between the worm thread *B* and the wheel by the line 2-2*A*, and on the worm thread *C* by the line 3-3*A*. In the right-hand view this worm has been rotated through an angle of 45 deg., the new line of contact being again shown dotted, only in this case the worm thread *C* has passed beyond the zone of contact and has thus ceased to contact with the worm wheel.

The illustrations (Fig. 2) show the one of contact for a four-threaded worm of the ordinary shape in which the teeth of the worm are straight-sided in section; that is to say, in the form of a rack. As the linear section of this type of worm corresponds to a straight-sided rack, and as the straight-sided rack forms the basis of the involute spur gear this shape of worm is generally known as the involute worm. As before, the zone of contact is shown in dotted line, but in this instance two teeth only are in contact in the left-hand view—*A* and *B*—giving lines of contact 1-1*A* and 2-2*A*, while in the right-hand view the tooth *A* carries the entire load along the line of contact 1-1*A*. The unsymmetrical contour of the zone of contact will be observed. More noticeable still is the difference between the irregular lines of contact shown on the end views of the involute worm as compared with the symmetrical lines of the F.J.

It must be understood that in both cases whenever the worm is revolved through an angle of 90 deg., the line of contact 1-1*A* will sweep across the zone of contact until it takes up the position marked 2-2*A*, because when a four-threaded worm is moved a quarter of a revolution (or 90 deg.), the thread *A* will naturally take up the position of the thread *B*. In the F.J. system it will be seen that the point 1 at the root of the worm (end view) falls into the position 2 after a quarter of a revolution; that is to say, the actual contact travels *in the same direction* as the worm through a distance of approximately 50 to 60 deg., hence about two-thirds of the motion is transmitted by a rolling action and only one-third by sliding. This means that a rolling action is introduced between the teeth of the gears, thereby reducing the ordinary rubbing velocity to a minimum. Thus the gear teeth, instead of rubbing against each other at, say, 1,000 ft. per min., really only rub at the reduced speed of about 350 ft. per min., due to the rolling action of the F.J. tooth contact.

This is not so on the involute worm-gear system. In the left-hand view in Fig 1 the point of contact 1*A* actually moves *in the opposite direction* to the rotation of the worm to the point 2*A*, thereby giving the rubbing velocity even more than its full theoretical value, while rolling action, at the ends *A* of the lines of contact, is absolutely non-existent.

A peculiarly inefficient characteristic of the involute system is that the extremities of the lines of contact (see plan view of worm) travel from positions 1 and 1*A* *toward each other* until they meet, and vanish just beyond the points 2, 2*A*, as shown in the left-hand plan view (Fig. 2).

The plan view of the F.J. system (Fig. 1) shows the point *A* always moving from left to right, in the same direction as the rotation of the worm, while the left-hand plan view of the "involute" system shows the point *A* moving very slightly from right to left, actually against the rotation of the worm. The high rubbing velocity which occurs on the point *AA*, together with the converging lines of contact which induce a concentrated load, all tend to produce the worst possible conditions on the leaving side of the worm wheel. This explains the well-known fact that when a worm gear of the "involute" type is overloaded, "pitting" first takes place on this side of the wheel, and on this side only, while those portions of the teeth on the entering side of the wheel remain unmarked.—*The Automobile Engineer*, December, 1919, p. 449.

MAKING DIAMOND WIRE-DRAWING DIES.

Diamond dies are extensively used for drawing small wire made of all kinds of metals and for sizes from 0.08 in. down they are used practically exclusively. Because of this the following data as to the manufacture of such dies by the Vianney Wire Die Works at Trefoux, France, become of interest.

For the manufacture of dies diamonds are used which are of a grade unsuitable for use in jewelry.

The firm standardized the size of diamonds from which dies of different diameters are made, the diamonds themselves ranging from one carat to sizes as large as twenty carats.

As is generally known, the diamond is so hard that it can be cut only with another diamond or diamond dust. The first step is the flattening of a rough stone, which is done with laps charged with diamond dust made by pulverizing small-sized diamonds or chips from larger stones and then grading

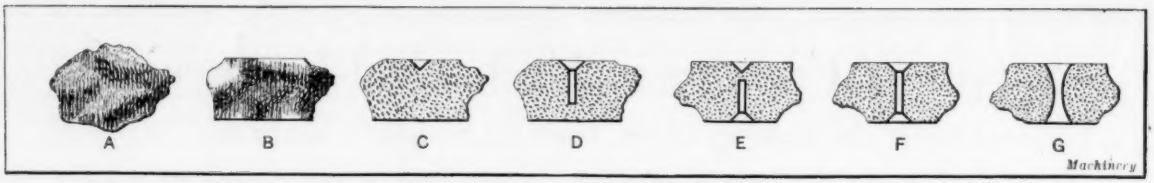

FIG. 3. ROUGH DIAMOND *A* AND CROSS-SECTIONAL VIEWS SHOWING SUCCESSIVE STEPS IN THE PROCESS OF MAKING WIRE-DRAWING DIES

the dust by sifting it through sieves with various numbers of meshes per square inch. This is succeeded by several operations, comprising the cutting of the die opening. The first step is to chuck the diamond on the faceplate of a special drilling machine and cut a conical-shaped opening, as indicated at *C*, Fig. 3. This opening is made by means of a diamond chip held by hand between the points of a pair of long-nosed pliers. After the conical hole has been cut, the drilling operation is started by means of a tool carried in the spindle of the machine, which is so designed that the table rotates and also has a vertical reciprocating motion imparted to it.

After the hole has been drilled about three-quarters of the way through the diamond, as indicated at *D*, the work is removed from the machine and turned over, after which it is reset and the conical opening is cut in the opposite side of the diamond, as indicated at *E*. Of course, this second conical opening has to be located exactly opposite the hole which has been drilled in the work. The next step is to drill from the bottom of this conical opening to make a connection with the hole entering the stone from the opposite side, *F*. It is very important to have the inside of the die absolutely smooth in order to prevent forming seams in the work and also to have the bell mouth of the die formed in such a way that the metal will pass into the die without undue frictional resistance. This is done by giving the die the shape shown at *G*. The inlet to the throat of the die is made slightly larger than the outlet at the back, which requires a great amount of dexterity to do. The dies are set in brass mounts.

The feature of diamond dies which makes them more economical in use than steel, cast iron or other comparatively inexpensive materials, is that they give a far greater amount of service before the tool is worn out, because of the extreme hardness of the diamond. The resistance against wear is also the means of maintaining greater uniformity in the diameter of the wire that is drawn through the die.

The time comes, however, when the die becomes too large to produce wire that comes within the specified limit of tolerance. When this point has been reached the dies is recut for a larger size, which is done by the use of a steel lapping tool charged with diamond dust. In connection with this operation the bell-mouthed opening must again be carefully finished to bring it tangent to the new throat which has been cut in the die and the inner surface must once more be carefully polished. The original article illustrates the special type of lathe used for refinishing diamond dies.—*Edward K. Hammond in Machinery*, Nov. 1919, pp. 264-266.

SALT PRECIPITATION BY REFRIGERATION

IN the chemical industry many salts have to be precipitated out of mixed solutions by means of crystallization. This is done by cooling the concentrated brines to the point where their ability to maintain the salts in solution is reduced.

Fig. 4 gives the solution curves of several salts in water, indicating how much of the salt at various temperatures may be contained in 100 grams of water (saturated solutions). As shown by these curves, the solubilities of various salts are unlike to an extraordinary degree and each salt permits to secure a greater or lesser precipitation out of a brine at a given temperature.

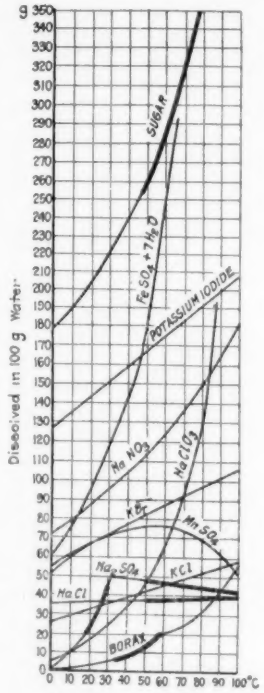

FIG. 4. SOLUBILITY CURVES OF VARIOUS SALTS

Thus, for example, in the case of Chilean saltpeter ($NaNO_3$) cooled from 90 to 20 deg. cent. (194 to 68 deg. fahr.), out of 165 grams held in solution at 90 deg. cent. so much is precipitated out that only 88 grams remain in solution.

The curves show that many brines can maintain quite considerable amounts of salt in solution even at 20 deg. cent. (68 deg. fahr.) and that substantial amounts of crystals are precipitated only when the brine is cooled to a much lower temperature.

Because of this, provision has to be made for certain salts to cool the brine to quite a low temperature and Fig. 5, for example, shows an installation built to precipitate out of its solution potassium chloride. In that case 3,000 grams of brine at 20 deg. cent. when cooled to — 10 deg. cent. (14 deg. fahr.) will precipitate out in crystal form 200 grams of potassium chloride.

The cooling is effected in two stages: by means of a water cooler to + 20 deg. cent. (68 deg. fahr.), and then in an ammonia refrigerating machine to — 10 deg. cent. (14 deg. fahr.).

The ammonia compressor *A* compresses the ammonia and forces it into a coil condenser *B*, in which ammonia under a pressure of 8 atmos. is liquefied by cooling water having a temperature of 15 deg. cent. (59 deg. fahr.). The liquid ammonia, the flow of which is controlled by a special valve, is then again vaporized in the coils *C* of the crystallization cooler *D*, the ammonia then going back to the compressor by means of pipe *E*.

The precipitation of the crystals is produced by cooling brine in cooler *B*, the salt settling mainly

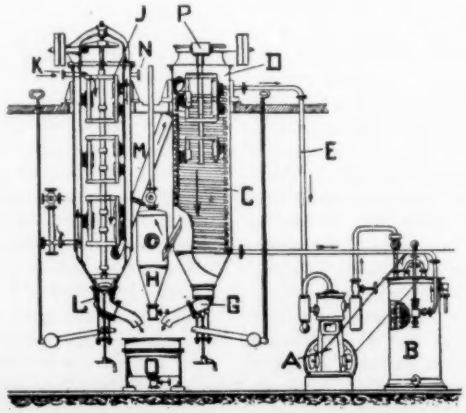

FIG. 5. EMIL PASSBURG INSTALLATION FOR PRECIPITATION OF SALTS OUT OF SOLUTIONS BY REFRIGERATION

on the cooling coils *C*. It is then swept off of them by special adjustable brushes, which also help to maintain the efficiency of the cooling action of the coil *C*. The crystals precipitated in this way sink through the brine and collect in the cone-shaped bottom of the cooler whence they are from time to time discharged into the straining tank *O* through a quick-acting valve *G*. It is necessary to have the valve of a quick-acting type in order to have the liquid pressure discharge the crystals containing brine without letting out too much liquid itself. The straining tank *O* has on top a fine screen on which the brine falls. The thin liquid passes through and is strained off while the crystals stick on top of the screen and are collected therefrom from time to time.

In the installation described approximately 6,000 calories (say, 24,000 B.t.u.) would have to be taken up from the refrigerating plant per hour. In order to reduce the consumption of cold the installation is so arranged that the brine which leaves the crystallizing cooler *D* at *H* is conducted to the jacket of a second crystallizing cooler *J* and on the way precools the fresh brine which enters at *K* with the temperature of 20 deg. cent. (68 deg. fahr.).

Brine entering with the temperature of — 10 deg. cent. (14 deg. fahr.) takes up heat to the extent of leaving the cooler *J* with the temperature of 5 deg. cent. (41 deg. fahr.), whereas the fresh brine which enters with the temperature at 20 deg. cent. (68 deg. fahr.) leaves with the temperature of 5 deg. cent. (41 deg. fahr.). The salt which is crystallized out in the meantime is swept away by brushes in the same manner as in the first cooler and precipitates out through the quick-acting valve *L* into the same straining tank *O*. In this manner the consumption of cold is reduced to about one-half.

In computing the consumption of heat in refrigerating installations of this type it is necessary to bear in mind that in addition to the heat which is necessary to cool the brine itself, quite considerable amounts of heat have to be taken care of as heat is given up in the process of precipitation by crystallization at the instant when the dissolved salt passes into the form of crystals, the amount of heat thus given up being the same as that which was previously consumed in order to dissolve the salt. In the case of cooking salt about 20 calories per kilogram (35 B.t.u. per lb.) were consumed, for potassium chloride ($KClO_3$) about 81.5 calories per kilogram (147 B.t.u. per lb.) and so on.—*Berthold Block* in *Zeitschrift für die Gesamte Kälte-Industrie*, August, 1919, pp. 57-59.

PUDDLED IRON PRACTICE.

NOTWITHSTANDING the impression prevailing among laymen today, steel is a comparatively recent product. Its general use, that is, aside from using tools, dates from the introduction of the Bessemer process in the middle of the last century. Until then the world knew iron in the form of either cast iron or wrought iron and when Kipling put into the mouth of one of his God heroes the line

"What iron called iron is master of them all?"

he meant just what he said, iron and not steel.

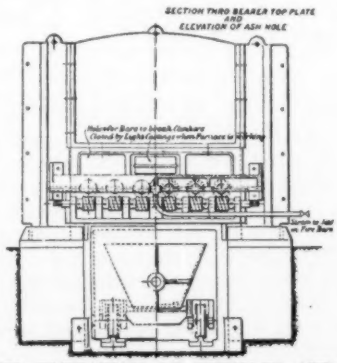

FIG. 6. END ELEVATION OF FURNACE ARRANGED FOR EASY REMOVAL OF ASHES

Bessemer first and open-hearth steel next proved to be in many respects superior to iron to such an extent that they displaced it practically forever.

Steel is better wearing than iron as regards mechanical stresses and after a while proved to be even cheaper. Because of this the production of puddled iron, which took on a new life with the invention of the Hall process about a score of

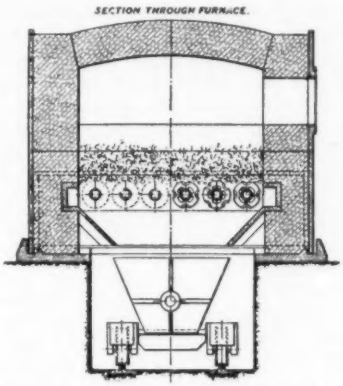

FIG. 7. SECTION THROUGH FURNACE SHOWING ARRANGEMENT OF GRATES

years before the invention of the Bessemer converter, lagged behind both commercially and technically. Scarcely any new furnaces for the production of puddled iron were set up previous to the war in the last fifty years, and some of those which were in existence have either shut down or converted to steel manufacture.

Nevertheless puddled iron has certain advantages over steel in its better ability to resist rust and heat.

This brought about an interesting revival of the puddled iron industry in the last few years.

Hall's process lies at the root of present and future puddling processes and is not likely to be superseded. It is conceivable that further attempts may be made to produce wrought iron directly from poorly silicious ores or by the decarburization of cheaply produced mild steel, but there are fundamental difficulties in the way of success affecting the character of the crystalline structure and the related welding and fibering properties of the resulting product.

There are three factors in puddling that affect the entire situation. These factors are:

1. The puddling furnace as we know it is one of the most wasteful of metallurgical furnaces using more fuel per ton of product than any other continuous process.

2. The labor cost per ton is abnormally high as is also the cost of furnace upkeep.

3. The rolling, shingling and material handling and transport plants are usually crude and excessively wasteful in power cost per ton of product.

The writer vigorously criticizes the design of coal-fired puddling furnaces, claiming that the radiation losses in such a furnace and its waste heat boiler amount to at least 20 per cent of the heat energy of the coal burned, or equivalent to, say, 560 or 784 lb. per ton of puddled-iron heat, whereas in the steel furnace the radiation losses do not exceed 224 lb. per ton of steel cast.

The radiation losses in a puddling furnace per unit of metal charged average from 10 to 15 times as much as in the open-hearth steel furnace, and so on.

On the whole, the author comes to the conclusion that the small furnace used in puddling is a real obstacle to fuel economy as its relatively large hearth causes the excessive radiation areas.

The construction and proportions of the modern puddling furnace are not likely to be substantially altered or improved, but it is possible to improve the grate and firebox and to provide efficient means for burning the poorer coals—in partic-

ular, to reduce the amount of unburned fuel that goes into the ashpit. Figs. 6 and 7 show sections of a furnace arrangement designed by the author.

The grate consists of a series of tubular bars perforated for air ejection, over which a number of specially shaped chilled cast-iron disks are threaded. These form a kind of roller grooved longitudinally, so that when it is rotated it causes clinkers to crack and burned ashes accumulated in the troughs between the roller bars to roll into the ashpit.

The air required for combustion is forced through the tubes by steam jets and passes out through the perforations into the fuel bed and ashpit which is closed by the front plate of the ash-removal car. The air ducts between the grate disks are nozzle-shaped and the grates can be cleaned without opening the doors. Large clinkers can be removed through the large holes provided above the grate in the firebox plate.

The application of gas firing to small puddling furnaces has also been suggested and a furnace was built with a small producer at the firing end.

The process of puddling covers three stages, namely, the melting stage, occupying 30 to 40 min. depending on the class of pig iron used and the efficiency of the fuel; the boiling stage occupying 30 min.; and the drying and balling, followed by fettling and charging periods, occupying about 40 min.

It appears further than the melting period demands, under the present conditions, from a little over 5,000 lb. to close to 6,000 lb. of coal per ton of metal melted and is the most wasteful stage of the puddling process.

Cupola melting which would be more economical as far as fuel consumption goes is not suitable as it yields a higher-carbon metal and very little reduction of the remaining metalloids, and because of this the boiling period in the puddling furnace is lengthened.

The author proposes a special method of procedure based on manipulation of the slags with a view to producing a low-sulphur metal from the cupola described in the original article.

The characteristic feature of the new process is the addition of manganese at a certain stage which causes a delay in the elimination of the carbon, while it accelerates the elimination of silicon and phosphorus. A liquid slag resulted and the metal poured flows easily and is well deoxidized.

The author also proposes the design of a plant consisting of an open-hearth tilting or fixed basin-lined furnace, the waste heat from which is used in attached efficient boilers fitted with auxiliary fuel supply apparatus, this latter having the purpose of increasing the steam requirements during the charging and tapping stages. From the open-hearth roughing furnace the metal is ladled to mechanical puddling furnaces fired with pulverized coal and having waste-heat boilers attached to them.

Each of the units composing the proposed plant are at work. The open hearth furnace is regularly melting iron on a pulverized coal consumption of 448 to 560 lb. per ton of iron melted. Puddling furnaces similarly fired are operating on a consumption of 1,300 to 1,600 lb. per ton of puddled bar, when dealing with cold pig iron. When puddling molten charged material the coal burned should not exceed 800 to 1,000 lb. per ton of product, six furnaces doing the work of the present ten.

If the roll trains and shingling machines or squeezers be operated by electrical power, and they can be, it is conceivable, that, given cheap electrical energy, such a combination of the duplex system with mechanical puddling furnaces and with electrical rolling and shingling equipment should furnish the most economical puddling plant possible.—Paper by *J. E. Fletcher* before the Staffordshire Iron and Steel Institute read Nov. 22, 1919, abstracted through *The Iron Trade Review*, Jan. 8, 1920, pp. 152-156.

Progress in the Field of Electricity

Summaries and Excerpts from Current Periodicals

A SUBSTITUTE FOR PLATINUM CRUCIBLES IN ELECTRIC ANALYSIS.

RECENT experiments in the Chemical Institute at the University of Bonn have shown that the platinum vessels, customarily employed as cathodes can be advantageously replaced by glass vessels whose inner surface is silvered. In order to obtain a layer of silver which will adhere closely to the vessel the inside of the latter must be treated with a sand blast, so that the surface resembles that of ground glass. It is less advisable to produce this effect by means of the vapors of acids, since this method does not usually produce so uniform an effect. Before the first application of the silver the vessels must be thoroughly cleansed with chromic acid then with soda lye and finally with nitric acid.

The silver solution employed consists of an ammoniacal solution of silver nitrate which has been reduced by the addition of 2 ccm. of a 40 per cent formalin solution. At a temperature of not more than 30° C. there is obtained in from three to four minutes a silver precipitate of from 0.03 to 0.05 grams, which has a uniform mat surface, and which is dark blue in color by transmitted light. The vessel is then dried and provided with a strip of sheet platinum, 2 mm. in breadth, one end of which must touch the silver coating, while the other is bent so as to hang over the edge of the vessel outside; this end is provided with a screw clamp. Other experiments, having as their object the replacing of platinum anodes by carbon anodes, have thus far yielded poor results, but will be continued with Acheson carbon. The glass cathodes just described gave excellent results in tests made with copper, cadmium, zinc, nickel, cobalt, and mercury, showing that they could readily be used as substitutes for the platinum vessels whose cost is now almost prohibitive.—*H. Gewecke* in the *Chemiker Zeitung* (Berlin).

A SUPER-POWER TRANSMISSION SYSTEM.

IN the territory between Boston and Washington and inland from the coast averaging 100 miles, which territory may be described as the finishing shop of American industry, there is an installed machine capacity of 10,000,000 horse-power. At the same time the load factor of this great regional demand for power is not more than 15 per cent. This means that for every 15 h.p. required 100 h.p. is installed. Today, due to improper form of power generation and distribution, for every ton of coal burned another is wasted—literally thrown away.

It is quite amazing to learn that there is shipped into the eastern territory 37,000 tons of coal daily for public utility central stations. The total coal tonnage used by all the electric power plants engaged in public service is only 95,000 tons daily, and thus in only a part of the zone under discussion, representing less than 5 per cent of the total area of the United States, there is required 40 per cent of the total amount of coal so used. Again, to ship this amount of coal

into this district requires over 800 cars in and out every day. This would represent a solid train of coal cars seven miles long.

If it is further considered that our coal fields are being rapidly exhausted and that our merchant marine is soon to carry the products of our industrialism the world over, it is clear that we must have economical power, *i. e.*, cheap and reliable power. Especially is it true of the territory under discussion where the power must in a large measure be furnished with fuel as a base. Economical power is the sole remaining means to prevent this finishing shop of American industry from being converted into the playground of American tourists.

The solution lies in the construction of high powered, high economy tidewater steam and hydroelectric stations and steam stations erected at the mouth of mines, within the territory named, all interconnected with a super-power transmission system, using also the large plants now in existence in the larger cities, such as Boston, Providence, New York, Philadelphia and Baltimore. The present companies would maintain their present entities, carrying all their present franchise rights; they would become merely distributers of power. The districts in which they operate would receive power in bulk from the super-power system at the points of their present stations and substations to be erected.

This plan has the hearty endorsement of the engineering press and of such societies as the Boston branch of the American Institute of Electrical Engineers, the National Electrical Light Association and of the Engineering Consul. Furthermore, it has the approval of Dr. George Otis Smith, Director of the Geological Survey, and of Secretary Lane, who is asking Congress to provide sufficient funds to the Department of the Interior by which an investigation can be made to allocate the losses now sustained and to be inclusive of recommendations covering a power transmission and distribution system by which they may be saved.

It is admitted that the financing of such an enterprise will involve the expenditure of a very large sum of money, which, however points to the truth that we are not only upon the eve but in the realm of far larger things than have concerned us in the past. Yesterday we were willing to spend a million dollars in construction to save one hundred thousand a year. Today we are ready to spend a billion to save a hundred million a year. "We have spent billions for destruction for preservation, now let us spend billions for construction for conservation."

It is estimated that the following advantages would result from such a super-power transmission system: (1) The power required in the industries of the zone under discussion as well as for its aggregate of 7,000,000 h.p. steam locomotives would offer unexampled opportunity in the application of diversity factor, that is power delivered from the same source to different points at different times; such a system would have the maximum load factor possible and the lowest coal consumption, resulting in an annual saving of $3,000,000 to the nation. Moreover, if the curves of recent progress are continued the electric power used in New England will increase four fold and the economies of the future should greatly exceed the figure given above. (2) It would release the railroads from the hauling of the 50 per cent of the coal now transported. This is very important as the limit to industrial expansion is likely to be the transportation facilities. If industrial expansion is to continue the railroad facilities must be increased, and the way to increase them in congested regions is by electrification. This not only increases the traffic capacity of tracks and terminals but it reduces the coal required for railroad operation. A general electrification of industry will further reduce the coal to be transported, thereby releasing the equipment for industrial freight.

3. While the cost of power does not represent more than 5 per cent of manufacturing cost, yet electricity *is* the agent of highest efficiency in power application and the greatest agent to *facility*. This country is to produce more and more if it wishes to maintain its supremacy in world's trade. Even if the cost of the application of electricity were twice as much as steam, its contribution to the facility of production, in nearly every form, would far outweigh the additional cost. Especially is it true of New England which is a manufacturing community without raw materials or coal.

4. Such a system would provide continuity of power production—due to an established breakdown service between power centers, and would greatly do away with fuel crises, such as was faced by New England in the winter of 1917-18.—*W. S. Murray* in the *Journal of the American Institute of Electrical Engineers*, January, 1920. Address delivered before the Connecticut Chamber of Commerce.

RADIO-TELEGRAPHY BY INVISIBLE INFRA-RED RADIATION.

J. HERBERT STEVENS and A. Larigaldie have perfected a detector apparatus, particulars of which have recently been communicated to the Paris Academy of Sciences. With their device they have been able to obtain records of infra-red radiations over distances of more than 20 km., the best results being obtained with a thermocouple.

In the tests as carried out the source of emission was an arc or electric lamp projector, the luminous flux of which was absorbed by a filter screen, a black glass coated with manganese dioxide or gelatine. These screens absorb 50 per cent of the total energy, but do not allow any rays which may affect the eye to pass.

The receiver is a parabolic mirror arranged to trap the maximum of radiant energy; the thermophile being placed at the focus of this mirror.

A metal plate 1/100 mm. thick is autogenously welded to the point of a crystal of high thermo-electric power. The thickness of the plate and the diameter of the point of contact were kept as low as possible so as to form a whole of very low thermal capacity. The best results were obtained with a platinum plate and a crystal of tellurium tempered and welded in the direction of crystallization. The junction is enclosed in a glass bulb having a fluorine window.

The thermocouple is mounted at the terminals of a lamp amplifier, the current being broken by a ticker of musical frequency. A potentiometer is connected up in the circuit in order to obviate all eddy currents due to the surrounding conditions which might cause a difference of constant temperature between the two junctions.

The diminuntion in the radiant energy captured at the receiver is generally proportional to the distance covered from the transmitter, but regard must be had to the absorptive power of the atmosphere, which is sometimes low and sometimes considerable according to the proportions of water-vapor, fog, dust, and CO_2.

Where the thermophile is not used in telegraphy but in pyrometry, in tele-mechanics, or for revealing the presence of bodies whose temperature differs from that of the surroundings (*e. g.*, icebergs at sea), its current is passed into a fairly sensitive galvonometer to give a deflection of 3 to 4 mm. per micro-ampere (2 to 3 ohm coil).

For ships the authors have designed a special double pivot galvanometer of the same sensitivity as the previous one, which is capable of working in any position and is unaffected by pitching or rolling.

The following tests made are worthy of mention:

(1) In September, 1918, signals were exchanged between two stations 14 km. apart. The transmitting station was provided with an arc projector of 1.50 m.

(2) In May of this year signalling experiments were made between two stations 7,500 meters apart. At the transmitting station there was a 0.40 m. mirror and an 800 watt nitrogen-filled electric lamp; while at the receiving station a gilt mirror of 0.24 m. was used. (Genie Civil, Aug. 2, 1919.)

AUDIBLE ELECTRIC SIGNALS IN INDUSTRIAL PLANTS, AND ACOUSTICAL ENGINEERING.

UNDER the impetus of the pressure for greater efficiency and increased production the modern plant finds it a paying proposition to install a system of loud acoustic signals. Such electric signals are usually similar in construction to the familiar electric "horn" used on automobiles. It consists of a diaphragm with an anvil at its center. A toothed wheel driven by a small electric motor strikes the anvil many times a second and causes it to vibrate vigorously. These vibrations produce the well known warning tone, which carries over a considerable distance. The device is provided with a projector or horn the shape of which depends on whether it is desired to scatter the sound, to intensify it in horizontal direction, or to deflect it downward. Such motor driven signals are now made much more powerful than automobile horns, and are wound for 110 or 220 volts, direct or alternating current, so that they can be connected to a lighting or power circuit, and do not require a separate low-voltage battery. By means of these signals calls could be given only imperfectly by pushing a button, and for this reason a special code calling instrument has been developed, which closes electric contacts automatically, after having been set for a desired combination; it can also actuate a bell, a buzzer or an electric lamp.

The uses of such electric signals are many, and their prime advantage in each and every large plant is the elimination of the waste of much time usually lost by the officials, experts and important employees in trying to locate each other. With loud signals installed throughout the plant it becomes possible to locate any of a considerable number if men instantly, using a simple code call for each. In noisy places—steel mills, textile mills and printing establishments—they are used as extensions to telephone bells. They can also be used as warning signals on cranes, local signals at various furnaces and rolling mills. Their importance in increasing the efficiency and safety in shipyards and coal mines should not be underestimated. They are equally applicable to construction jobs where, in the absence of electric power, they could be operated from 6-volt storage batteries. A large number of such horns have been recently installed on various U. S. naval vessels as fire alarm signals, for general alarms, as hoist signals and also for code calls throughout the ship. At large public gatherings, conventions, festivals, etc., such a system of signals could reach any one of the participants which is wanted either by the executive committee or for delivery of important mail, etc. A new application of audible signals well worth looking into is the hold-up alarms for banks. With a masked man pointing a revolver at him, the teller could press a push-button with his foot, which would cause an alarm to sound at the next street corner, or somewhere in the building where certain men have been trained and armed for such an emergency.

In industrial plants and other places in which acoustic signals will be gradually installed, the engineer will soon be confronted with various acoustical problems: the indistinct noise known as reverberation, sound interference, consonance, echoes and zones of silence. Fortunately, physicists and architects have done some splendid ground work in this direction. Prominent among them is Prof. Wallace C. Sabine of Harvard Univresity, who made numerous tests of the relative absorbing power of different substances, using organ pipes as the source of sound. Other investigations on transmission, reflection and absorption of sound by different materials were made by F. R. Watson, by H. D. Taylor and by C. S. McGinnis.

Prof. A. L. Foley of Indiana University opened a field of many possibilities in experimental acoustics by perfecting the method for directly photographing sound waves. These photographic researches promise a method for an experimental study of sound waves under conditions which are too complex for theoretical computations. Dr. Sabine has applied this method to the solution of acoustic problems in some theaters. It is quite possible that this method may prove of utility in the solution of similar acoustic problems in industrial plants. Photographs taken on models of complicatel shipyards, coal mines or a mill full of machinery may explain some observed abnormal conditions, such as zones of silence and a departure of the sound intensity from the simple law of inverse squares.

If acoustics is to become a branch of applied science simple and robust instruments must be developed for measuring the physical quantities involved, particularly the sound intensity. An electric horn may be guaranteed to produce a sound intensity of so many "Carusos" per square centimenter, at a distance of say one hundred meters from its diaphragm. The need of such instruments has already been felt in connection with fog signals. A simple indicator of sound intensity is the so-called Rayleigh disk, which has not been used much in practical acoustical measurements. An instrument of considerable accuracy and sensitiveness for measuring sound intensity at a point is the phonometer developed by Dr. A. G. Webster, of Clark University.

A sensitive telephone receiver may be used for measuring the sound intensity, as the current induced in its windings is proportional to the sound intensity. The induced currents are measured by a crystal rectifier and a dic. galvanometer, or by means of a very sensitive vacuum thermometer. Prof. Miller's phonodeik distorts the relative magnitudes of the harmonics and requires tedious corrections to reconstruct the actual sound wave.

It is evident that the question of selective sensitiveness of the human ear must also be considered, and the energy measured only within the audible range; the range of maximum sensitiveness of audibility lies between 700 and 3,000 vibrations per second. Systematic experiments will be needed on the sensitiveness of the human ear not only to sounds of different pitch, but to the same sounds accompanied by disturbing noises. Only a beginning has been made in this direction.

The diaphragm is the most essential part of an electric horn. A large number of investigators have worked on this problem in connection with the telephone, phonograph and other reproducing devices. The problem is further complicated by the fact that the diaphragm is seldom used alone but usually has a horn associated with it. This horn adds its natural frequencies due to the enclosed air and thus modifies the properties of the diaphragm itself. Besides, there are unavoidable little cavities where the diaphragm is built into a housing, and these cavities act as resonance chambers adding to the troublesome selective sensitiveness of the combination. A systematic study of these factors is still in its infancy and offers a big and fruitful field for the future investigator.—*V. Karapetoff* in the *Journal of the American Institute of Electrical Engineers*, January, 1920.

EFFECT ON EXPOSED WIRES OF THE ELECTRICAL CHARGES CARRIED BY RAIN-DROPS.

TO INVESTIGATE the causes of the electrical disturbances in air lines and the changes, often without apparent cause, in the pressure and current-intensity in electrical networks, and to see if they could be accounted for by the electrical charges carried by rain-drops, the authors carried out experiments with an insulated copper wire 100 meters in length. They have found that the charge on the insulated wire is sometimes of the same and sometimes of opposite sign to that of the charge carried by the rain. The potential of the wire frequently exceeded 1,000 volts, and it was not uncommon to obtain sparks of 2 or 3 mm. between an extremity of the wire and an earthed plate. The authors conclude that an insulated wire acts as an equalizer of potential, and that, therefore, the disturbances are caused by the earth's electrical field, rather than by the charges conveyed to the wire by rain. —*A. Baldit, Comptes Rendus*, Nov. 17, 1919. Abstracted through *The Technical Review*.

Progress in Mining and Metallurgy

Abstract of Papers to be Read at the February Meeting of the American Institute of Mining and Metallurgical Engineers, and Summaries of Important Articles in Current Periodicals

Prepared Under the Auspices of the American Institute of Mining and Metallurgical Engineers

ELECTRIC FURNACES FOR NON-FERROUS METALS.

ELECTRIC FURNACES are now in actual use for the melting of brass, aluminum, zinc and other metals. Attempts to utilize furnaces of the arc type for melting metals which readily oxidize and volatilize resulted in comparatively high metal losses. Recourse was therefore had to the induction furnace, but this type has been built for non-ferrous work only in units of small capacity, has a lower power factor, and is said to be comparatively costly in upkeep; the purely resistance furnace, on the other hand, has both a high power and load factor.

The heating element consists of a trough filled with a granular resister material, and although the furnace appears to be of large size in relation to output, metal losses are, it is claimed, reduced to a very low figure. On a six days' run on yellow brass scrap, the actual metal losses were 1.3 per cent., while during a period of six weeks the over-all metal losses were only 0.811 per cent. The resister troughs are said to have a four months' life, and the material with which they are filled a two weeks' life under normal operating conditions. Owing to the absence of intense local heating, the refractories are said to require renewal only at long intervals. Five of the furnaces are in use at one plant for melting an alloy which contains over 80 per cent zinc. They are made in sizes ranging from 40 kw. up to 1,000 kw., but the unit size more generally adopted is the 105-kw., round, hand-tilting type, which has a normal hearth capacity of 1,500 lb. and a melting rate of 600 lb. per hour.

Experience and commercial practice shows the current consumption to vary from 300 to 350 kw.-hr. per ton of yellow brass scrap melted. The larger furnaces, of from 500 to 1,000 kw., are of the rectangular nontilting or tapping type. The cold charge is introduced through motor-operated doors, and rabbling doors are conveniently placed. One of these furnaces, used for remelting aluminum pig, is supplied with 500 kw. and has a hearth capacity of 3 tons. The same furnace has a hearth capacity of 9 tons of brass, with a melting rate of 2 tons per hour when supplied with 600 kw. A 1,000-kw. furnace of this type is employed for melting zinc cathode, and has a capacity of 200 tons per day. Its operating sheets show that the percentage of metal dross averages 0.024 per cent. —Paper presented by *Verdon C. Cutts* at meeting of Institute of Metals held in Sheffield, England; published in *The Engineer* (London) of Oct. 10.

PULVERIZED COAL AND ITS FUTURE.

REMARKABLE strides have been made recently in the adoption of pulverized coal as a fuel for stationary boilers, and this development is now attracting considerable attention. Pulverized coal was burned in boiler furnaces, but with destructive results to the refractories, because the fuel, being in suspension in nearly a gaseous condition, was burned in furnaces designed for other methods of firing.

In the earlier days, the coal was not pulverized to the present standard degree of fineness and also it was not as carefully dried. Furthermore, it was introduced into the furnace at too high pressures, with a resulting blowpipe effect which created local zones of high velocity gases in the furnace, against the refractories.

It was not thoroughly understood that there was a certain relation necessary between the volume of the combustion chamber and the quantity of fuel fired per unit of time. The many continued attempts that were made developed the fact that the basic reasons for the destructive conditions in the furnace were contracted volume and excessive velocities of the gases of combustion passing through the furnace. It has been found that the maximum velocity that can be maintained without destruction is 7 ft. per sec. This, stated in terms of boiler horse-power developed, would equal approximately 2 cu. ft. of furnace volume per boiler horse-power developed, assuming that the combustion chamber was nearly in the form of a cube. The limiting feature would be the velocity of the gases through the smallest cross-sectional area and where the highest temperatures prevail. Absolute control of furnace temperatures prevents to a great extent refractory troubles and consequently reduces furnace maintenance.

ADVANTAGES OF PULVERIZED COAL AS A FUEL.

The principal reason for pulverizing coal is to make it burn more easily. Combustion is continuous. Pulverizing permits of a more complete mixture of the particles with the air, so that complete and practically perfect combustion is obtained with a low percentage of excess air. When coal is pulverized to the standard degree of fineness—that is, 95 per cent through the 100-mesh sieve and 85 per cent through the 200-mesh sieve—its surface exposure is increased between seven and eight hundred times and the number of particles in a cubic inch of puverized coal of this fineness is somewhere between 500,000,000 and a billion. The subdivision of the particles of combustible is so great that they exceed even that possible of attainment by the use of oil in the present oil burners, and therefore higher efficiencies are possible, due to the better mixing of the fuel with the air, than can be expected by burning fuel of any other kind, except, possibly, natural gas, or by using any other method of burning coal.

The furnace contents previously specified refer to the use of pulverized bituminous coal in stationary boilers. The same general rule holds good for all high volatile coals or coals in which at least 25 per cent of the total combustible is volatile matter. Where other fuels are concerned, such as anthracite or coke breeze or any other grades of low volatile fuels, the furnace must be designed to suit these fuels. Where low volatile coals are burned, it is necessary to locate the burners through which the fuel is introduced to the furnace at a point sufficiently close to the flow of the products of combustion on their way to the boiler, in order to assist the initial ignition of the fuel by a regenerative action in the furnace, and this action can only be obtained by the return flame approaching near the jets of fuel entering the furnace.

LOW-GRADE COALS CAN BE USED.

All grades of coal can be burned in pulverized form and all grades of commercial coal can be burned with high efficiency regardless of the percentage of ash. This method has opened up and made useful wide fields of low-grade coals hitherto not available due to their peculiar nature. Among these might be mentioned lignite coals, graphite anthracite coals of Rhode Island, and also various kinds of waste fuels from mining operations.

There is practically a complete elimination of standby losses

where pulverized coal is used. If the firing operation ceases the doors are closed. No air is allowed to pass through the furnace and the radiant heat of the furnace is absorbed by the boiler. There are no metallic parts exposed to the action of the heat and interfering with continuous operation in pulverized coal burning. There are no fuel beds or clinkers to interfere with the air supply. The arguments, therefore, in favor of pulverized coal method of firing appear very strong.

COST OF PREPARATION.

The adoption of this method of firing, however, for any particular installation, depends strictly on the cost of preparation. The cost of preparation varies with the quantity of fuel burned daily and it is a question of the profit in sight as to which equipment will show the greatest returns on the investment for any plant of a given capacity. In the table here shown, the first two items are nearly constant. The drier fuel will vary slightly, according to the price at which coal is received. The cost of labor diminishes as the quantity of coal increases. The power is assumed to cost ¾c. per k.w.-hr. The repairs at 7c. per net ton. The drier fuel is based on coal at $5 per net ton delivered with an average moisture content of 7 per cent, assuming that 6 per cent of moisture would be driven off per pound of coal in the drier. The furnace labor is assumed at 50c. per hour.

Cost of Pulverizing and Delivering the Pulverized Fuel to Boiler Furnaces

Daily Capacity, Tons	Cost of Labor, Cents.	Number Labor Hours	Repairs Cents	Drier Fuel, Cents	Power	Cost of Pulverizing Cents
20	30	12	7	6	13	56
30	30	18	7	6	13	56
40	25	22	7	6	13	51
80	20	32	7	6	13	46
120	18	42	7	6	13	44
160	17	48	7	6	13	43
240	13	62	7	6	13	39
320	11	72	7	6	13	37
400	10	83	7	6	13	36
480	9.5	94	7	6	13	13.5
640	8	104	7	6	13	34
800	6.75	108	7	6	13	32.75
960	6	114	7	6	13	32
1;120	5	116	7	6	13	31

No interest, depreciation, insurance or taxes have been included in the above total.

The cost of pulverizing should not be considered as an additional expense in the preparation of the coal in pulverized form, when comparing the total cost of handling fuel with the best stoker-fired practice, because the handling of coal in stoker installations, which includes the crushing and handling of the coal to the stokers, the cost of power for driving the crushing, elevating, and conveying equipment, stokers, and fans for air supply, together with the repairs on the entire equipment, amounts to from 30 to 60c. per ton coal fired, depending on the size of the plant. Address to Philadelphia Section, American Society of Mechanical Engineers, Oct. 28, 1919, by *H. G. Barnhurst;* published in the *Journal of the Engineers' Club of Philadelphia*, December, 1919.

BLAST-FURNACE FLUE DUST.

By R. W. H. ATCHERSON.

BLAST-FURNACE flue dust is one of the most troublesome operating factors in the iron and steel industry. Several successful operators claim that it is useless to recharge raw flue dust because the furnace would never have blown it out if it had been suitable material for blast-furnace consumption. Yet some very remarkable results have been attained at the Ohio Works of the Carnegie Steel Co. through recharging raw dust. The plant comprises six modern blast furnaces. Up to 1909, about 300,000 tons of flue dust had accumulated in stock piles. During the last 10 years, there have been recharged into these furnaces all of the flue dust recovered from the furnace operations, the entire stock pile of flue dust, and nearly 80,000 tons of dust shipped from other furnaces of the Carnegie Steel Co.

In common with a great many blast-furnace men, we have tried many schemes for reducing the amount of dust carried out by the gas and numerous ways of recharging it, in both the raw and the sintered state. We have operated on inconsiderable percentages of Mesaba ore and again have used nothing but Mesaba for years at a time. Yet we are still making a great deal of flue dust, probably not any more than the average blast furnace using fine ores, but the amount is out of all proportion to any physical changes in our ores and has never been as low as in some furnaces that are being driven at about the same rate of pig-iron production.

I believe that much of the opposition to the use of fine ores in blast furnaces is superficial and prejudicial. Burdens composed entirely of fine ores are being very successfully handled by furnaces built on lines as developed today. High flue dust production, where prevalent with high percentages of fine ores in the burden, is frequently due to an improper mixing or sizing of the ores. Where no thorough effort is made to counteract the natural segregation of lumps and fines at each rehandling from the mines to the furnace, there is bound to exist in the blast furnaces strata of ore of a finer consistency than contiguous layers. The obvious requirement of these finer and denser layers is an augmented gas pressure, sufficient to force through the denser layer. The action is rather more violent than would be the normal flow of gas and is attended by a greater disturbance of the stock, resulting in a larger production of dust than would follow the passage of the gas through the more open layers of ore. As a means of limiting the segregation of the fines into layers in the furnace, the method of charging is of incalculable value as a corrective feature but is not sufficiently thorough to counteract indifferent handling at the mines and docks. The intimate mixture of each ore into a uniform material physically also brings about a much desired chemical equality.

From any view point, coke is the very life blood on which the whole smelting process depends. The physical structure of the coke has a very much greater influence on every phase of blast-furnace practice than has the structure of any of the other materials. As indicating the effect of soft coke on flue-dust production, a comparative statement is given, covering two operating periods on the same furnance under apparently identical conditions aside from the coking time on the by-product ovens. While using the soft coke, so much of it was dissolved in the furnace stack that it was found advisable to decrease the volume and increase the temperature of the blast and to charge additional coke while it was also necessary to use several times the normal number of scouring charges of Bessemer slag to keep the furnace working smoothly.

TENSILE PROPERTIES OF BOILER PLATE AT ELEVATED TEMPERATURES.

By H. J. FRENCH, MET. ENGR.

AT the request of a committee of the Engineering Division,[1] National Research Council, a study of the properties of boiler plate at various temperatures up to about 900° F. (482° C.) has been instigated. The paper is a report of preliminary tests made on two grades of ½-in. plate and includes a description of the apparatus used in the determination of the proportional limit. The steels tested were ½-in. (12,7 mm.) boiler plate of firebox and marine grades.

The test specimen was heated by means of an electric tube furnace, two spiral resistors in series being used. The furnace was operated on either 110 or 220 volts direct current, close regulation being obtained by two 15-ohm 30-ampere variable resistances in series in the circuit.

In both grades of plates increase in temperature from 70°

[1]Committee on Physical Changes in Iron and Steel Below the Thermal Critical Range, Dr. Zay Jeffries, Chairman.

to 870° F. (21° to 466° C.) is accompanied by distinct changes in strength and ductility, viz.: (*a*) The tensile strength at first decreases a few thousand pounds per square inch, reaching a minimum at about 200° F. (93° C.). This is followed by an increase up to about 550° F. (288° C.) where the tensile strength reaches a maximum about 10 per cent greater than the normal room temperature value, after which another and final decrease occurs. (*b*) The percentage elongation in 2 in. (5 cm.) decreases rather slowly up to about 200° F. (93° C.) after which it drops more rapidly, until a minimum is reached at about 470° F. (243° C.); this factor then increases throughout the balance of the range under consideration. (*c*) The reduction in area closely follows the inflections registered in the curve for elongation, but has a minimum at slightly higher temperature than the elongation. (*d*) The proportional limit at first increases slightly and shows a maximum in the neighborhood of 400° F. (204° C.) for the firebox plate and the highest values between 200° and 300° F (93° and 149° C.) for the marine plate. It is noted that both the actual and the percentage increase are much greater in the case of the firebox grade and that the subsequent and final decrease in proportional limit for this plate takes place more sharply than in the case of the marine grade of boiler plate.

AN EXPERIMENTAL GUN CONSTRUCTION

By P. W. Bridgman.

During the war, the Navy undertook the construction of an experimental gun embodying features designed to lessen the cost and time of production. These experiments were initiated after representations as to their desirability had been offered by myself, by the Naval Consulting Board, and by the National Research Council. The first drawings were made in June, 1917, and the experiment was completed in November, 1918.

For the sake of clearness it will pay to recapitulate briefly the fundamental idea of gun construction. It is well known that if a hollow cylinder is subjected to internal fluid pressure, the maximum stress occurs in the inside layers, the outer parts carrying much less than their due share of the stress. This inequality of stress is more pronounced the thicker the walls of the cylinder. If such a cylinder is pushed to the elastic limit, failure in elasticity will take place long before the outer layers have reached the limit of their capacity. Economical use of the material would demand, however, that all parts of the cylinder reach the limits of their capacity simultaneously. This may be brought about, at least in cylinders of not too great thickness, by producing in the inner layers an initial compression, and in the outer layers an initial tension. The effect of internal pressure is at first to relieve the compression of the inside layers, while increasing the tension of the outside layers. If the initial stresses are properly distributed, all parts of the cylinder will reach their elastic limits simultaneously, thus giving a cylinder of maximum strength for its weight.

In gun construction as hitherto practiced, this initial distribution of stress is produced either by winding the inner tube with wire, a common English practice, or by shrinking hoops over the innner tube, which has been the standard American practice. Either process is long and expensive.

There is another possible method of producing the desired internal compression. If a heavy cylinder is stretched considerably beyond its elastic limit, the inner layers flow and the outer layers receive a permanent stretch. On release of pressure, the outer layers shrink back on the inner, producing an internal compression, and of course, an equilibrating tension in the outside layers. If now pressure is reapplied, it will be found that the elastic limit has been raised to the previous maximum pressure. It is possible to raise the limit in this way to two or three times the value as calculated by the usual theories. This behavior of cylinders under high internal pressure was demonstrated experimentally, and has been continually used in the construction of apparatus for my high-pressure experiments at the Jefferson Physical Laboratory since 1906. In these experiments I have accurately measured hydrostatic pressures as high as 300,000 lb. per sq. in. (21,090 kg. per sq. cm.), pressures which would have been unattainable except for this behavior of thick cylinders when stretched beyond the elastic limit.

With regard to gun fabrication, it has been demonstrated by actual construction and firing tests that it is possible to make a gun from a single forging, producing the required distribution of internal stresses by a preliminary application of hydrostatic pressure so high as to strain the material considerably beyond its yield point. The great simplicity of construction by this method leads to the expectation of important economies of time and money if quantity production should be attempted.

The technique of controlling the pressures required, which are of the order of 100,000 lb. per sq. in. (7030 kg. per sq. cm.), has been described as applied to the experimental gun. The essence of the technique is a packing which automatically becomes tighter at higher pressures. There is no reason to think that the technique should not be successfully applied on a commercial scale.

The behavior of the hollow cylinders composing the gun, when stretched by heavy internal pressure, has been described. Such cylinders flow and receive permanent set under pressures which may be about twice the elastic limit computed according to the simple theories. After once stretching, the cylinder receives little or no further permanent set up to the previous pressure maximum. Within this range of pressure, the cylinder behaves in a manner approaching that of perfect elasticity, but with very marked disturbances, of which hysteresis and accommodation effects are the most prominent. These disturbances tend to disappear with time. The approach to perfectly elastic behavior is much closer for thin than for thicker cylinders. A valid theory of the stress-strain relations under such conditions is much to be desired, but has not yet been formulated.

USE OF MICROSCOPE IN MALLEABLE-IRON INDUSTRY.

By Enrique Touceda.

As in the case of steel and the non-ferrous alloys in general, the use of the microscope in connection with the manufacture of malleable cast iron has proved of inestimable value to the industry. No fairer statement could be made than that the start of real progress in the industry was coincident with the application of metallography to the product.

The writer has been associated with the manufacture of malleable-iron castings since 1894. In 1904, he became convinced that while practical experience combined with close observation, when accompanied by a good metallurgical foundation, made possible the explanation and elimination of many of the troubles encountered, works' control could never be satisfactorily attained without proper facilities for a study of the structure rather than the fracture of the annealed product. Steps were then taken to secure the best metallographic outfit available and, with the aid of a small electric-resistance annealing furnace and this outfit, more knowledge was obtained in 3 months than in the previous 10 years.

It must not be assumed, however, that in all cases dependence on the use of this instrument alone will disclose the true and complete story, for what may be shown by the fracture, the structure, and the chemical composition must, in many instances be carefully considered before an accurate diagnosis can be rendered.

UNWATERING THE TIRO GENERAL MINE BY AIR-LIFT.

By S. F. Shaw, E. M.

In 1913, the Tiro General mine, at Charcas, S.L.P., Mexico, which had been making from 125 to 150 gal. of water per min., was allowed to become flooded, after all the pumps had been

removed, and in 1918 the problem of unwatering it came up for solution. There are two vertical shafts, the Tiro General, 1390 ft., and the San Fernando, 1225 ft. in depth, with five connecting levels between them. The San Fernando shaft had been partly retimbered while the Tiro General had been newly timbered from the collar to 1090 ft. in depth. It had been possible to place guides in only one compartment of the Tiro General, from the collar to the 7th or 850-ft. level, to which it was necessary to lower the water before station pumps could be installed. Soundings indicated that compartments in the Tiro General were open to 1082 and 428 ft., and in the San Fernando shaft to 471, 488 and 586 ft. The water had risen to a point 140 ft. below the collar of the Tiro General shaft.

The steam plant at the Tiro General shaft includes one 300-h p., one 150-h.p., and one 100-h.p. Erie City water-tube boilers, and two 160-h.p. Heine water-tube boilers. All but one of these boilers were supposed to be in good shape, but it was soon discovered that six years of idleness in a climate that is foggy for several months of the year had left them in poor condition. The compressed-air plant comprises one Nordberg cross-compound compressor with piston displacement of approximately 2,500 cu. ft. of free air compressed to 96 lb. per sq. in., and another Nordberg cross-compound with piston displacement of 1,235 cu. ft. of free air, to the same pressure.

The main pump station is on the 7th level where had been installed a Prescott potvalve plunger pump with capacity of 200 gal. per min.; also a Gould triplex plunger pump with capacity of 135 gal. per min., driven by a 6½ by 10 by 12 in. steam engine. From the lower levels the water had been raised to the 7th level by small station pumps and sinking pumps.

Although the submerbence of an air-lift pump at the final stage of unwatering to the 7th level would be limited to about 225 ft., we were assured by pump manufacturers that this point could be reached by a single-stage air lift, and we therefore decided to adopt this method. The equipment to be purchased consisted only of piping, foot pieces, etc., since the compressor plant was considered adequate for the purpose. Not only did we save the first cost of such equipment as sinkers, or centrifugal pumps and motors, but we also found that delivery of pipe could be effected in much less time than pumps and motors.

At the beginning of operations, two air-lifts were installed, one in the Tiro General and one in the San Fernando shaft. These were operated until it became evident that they were not suitable for the work to be required of them at greater depth; they were then removed and replaced by air-lifts of better design, designated No. 3 and 4. Since the lift involved in lowering the water to the seventh level, where steam pumps could be installed, was much greater than had ever been attempted before where a large quantity of water was to be handled, it was necessary to make many careful experiments as the work progressed, in order to anticipate the probable performance of the lifts that were installed.

LOW-TEMPERATURE CARBONIZATION OF COAL.

By S. W. Parr and T. E. Layng.

THE low-temperature carbonization of coal involves the carrying out of the coking process under conditions wherein neither the coal mass nor any of the passageways through which the volatile products pass are heated above 700° or 800° C. For convenience in this discussion, the single number 750° will be used to designate the maximum range. This temperature is not selected arbitrarily; it is the result of certain natural conditions that are inherent in the substances involved. Two of these conditions are sufficiently pronounced to suggest a line of demarcation at this point as follows: (1) Below 750°, all the heavy hydrocarbons are expelled, which means that, at these lower temperatures, the illuminants, the gases of high calorific value, and the condensible oils are discharged; above 750°, there are given off the lean, non-illuminating gases consisting for the most part of hydrogen and marsh gas and having no considerable constituents present. (2) Below 750°, there is substantially no secondary decomposition; above 750°, the volatile products are readily decomposed, forming tars, naphthalene, free carbon, etc.

It is acknowledged that the maintenance of these temperature conditions at the present time has only an ideal and not a practical status. Actual operations under these conditions, as an industrial accomplishment, are still in the experimental stage. However, many tendencies are working toward this goal and the topic is certain to be one of great interest until we have come much nearer the ideal in practice. There is a definite value, however, in setting forth in quantitative terms, so far as they may have been determined, the factors that represent the normal yield to be expected if conditions are maintaind as planned.

Attention is called to the following facts: The temperature conditions were maintained consistently throughout so that uncertainty on that point is eliminated. The yield of by-products from a given type of coal is sufficient in form to afford strong presumption as to the fact that these are the normal values that may reasonably be expected under low temperature carbonization conditions. The tars are of unusual interest and require further study to arrive at full information concerning this product. The gas yield represents usually high calorific values. The behavior of the sulfur is, in some respects, the most important of all the data. The coke is, in many respects, the most interesting product of all. It is sufficient at this time to say that the so-called non-coking coals of Illinois give promise of being advanced into the class of coking coals.

THE COEFFICIENT OF EXPANSION OF ALLOY STEELS.

By John A. Mathews, Ph.D. Sc.D.

DURING the prosecution of the aircraft-production program in 1917 and 1918, the writer visited many plants engaged in the manufacture of motors, planes and parts, in carrying out his duties as chairman of the Committee on Aircraft-engine Forgings. While the coefficient of expansion is not without its effect in volume changes in hardened steel, it is not a determining factor in the matter of distortion and going out of shape. Irregular heating, uneven furnace bottoms, and carelessness in withdrawing the part from the furnace, as well as the manner in which the part enters the quenching bath are of greater moment. Generally speaking, also, steels of relatively low hardening temperature will distort less than those requiring higher hardening heats. The coefficient of expansion must be considered in engineering design most frequently when different metals or alloys are used in the same construction. For example, the difference of expansion between a steel crankshaft and an aluminum crank-case might be of real importance and a steel with no coefficient of expansion would be much less desirable than one with the normal coefficient.

Through the coöperation and assistance of Major Heaslet and Capt. H. F. Wood, of the Detroit Branch of the Aircraft Production Department, the Committee was assisted in securing various types of alloy steels used for crankshafts; and in connection with them we have the analyses and tensile properties, also the hardness and shock-test values in several cases. The writer has supplemented this list with other types of alloy steels frequently used for axles, shafts, etc.; all of this material has been tested in a heat-tried condition, which has produced elastic properties between 100,000 and 150,000 lb. per sq. in. yield point. The Bureau of Standards coöperated with the Committee and made the actual tests of coefficient of expansion, which is a sufficient guarantee of the accuracy of the figures presented. We hope the complete data presented may prove of value to engineers and that future authors, in presenting data on the same subject, may follow the example we have set.

Progress in the Field of Applied Chemistry

Notes Culled from Current Technical Literature

GERMAN CHEMISTRY.

THE one excuse for again directing attention to the brand of chemistry which has been so well advertised is the apparent determination of Germany to regain the world markets which she once held due to the application of science to her commercial problems. There are still some who feel that there is a certain potency in German chemistry which we cannot expect elsewhere and hence we refer to the article entitled "The German Chemical Myth," by Benjamin T. Brookes, which appeared in the *North American Review* of November, 1918, and Mr. Townes R. Leigh's article on "Germany's Stolen Chemistry," which appeared in *Drug and Chemical Markets*. These gentlemen point out to what extent German chemists have failed to take part in work on the fundamentals of chemistry. In laying down twenty-one fundamental laws by which the science is governed, such men as Avogadro, Boyle, Charles, Dalton, Faraday, Henry, Mendelejeff, van't Hoff, Dulong and Petit appear, but nowhere is the name of a German to be found. Holland, Russia, Italy, France, England and America all appear.

The discovery of chemical elements shows at once what a small number of the useful ones have been discovered by Germans. Oxygen is credited to an Englishman; the discovery of nitrogen to a professor at Edinburgh University; carbon dioxide was isolated by a Scotch chemist; and the other rarer elements of the air were first discovered and studied by British subjects. Nor have the Germans discovered the elements of water—both hydrogen and oxygen having been first recognized as elements by Englishmen. Chlorine was discovered by Sheele, a Swede, and sodium, the other component of salt, by a Londoner, Davy.

In Buckley's "History of Natural Sciences," thirty of the chief men of science of the 17th century included but three of German blood. Twenty-seven of the 18th century include again but three Germans, and the majority of the important contributions to chemistry during the 19th century were not made by sons of the Teuton Empire.

If one considers the question by subjects, Professor Brookes points out that in the field of dyes every one has had a hand, but the origin was through Perkin in England. It was van't Hoff of Holland who first showed the Germans how to develop their potash natural monopoly. The phosphate industry, petroleum, and radium from carnotite ores are American. Nickel and cobalt are American and Canadian. The cyanide process so important in metallurgical operations is attributed to McArthur and Forrest in South Africa; electro-chemistry and aluminum to Hall, an American, and Heroult, a Frenchman. Artificial graphite and abrasives are American, cement is English and American, and the development of the use of powdered coal which made cement a possibility in Germany, is likewise an American invention. Hydrogenation, which one pro-German writer called a beneficial result of militarism in that large supplies of hydrogen made for balloon purposes could be used for the process, is French in its origin. Artificial resins are to be credited to a Belgian working in America, and to a Frenchman we credit organic compounds of magnesium.

Radio-activity, electrolytic dissociation, electrochemical action, spacial isomerism laws in heterogeneous systems, the law of atomic heats and of mass action, together with the law of conservation of mass and the atomic theory, are all of other than German origin, as is also the fundamental work on gases. It is seen therefore that while the fundamental work on chemistry has been almost universal, German names are conspicuous by their absence, and their prestige is really to be found in lexicons, text-books, tables of constants, not always too well done, and careful systems of systematic instruction. So far as ability is concrened, it should be apparent that the rest of the world is perfectly able to take care of itself; but chemists need assistance in preparing for themselves the kinds of things in which Germany has had a monopoly. We refer particularly to the compilation of Tables of Critical Physical and Chemical Constants and the preparation of other compendia of scientific knowledge more complete, more accurate than have appeared heretofore and in the English language. The English-speaking people are coöperating on this work, but there is need for material support in the undertaking that is so large and yet so important that industry can properly be expected to do its part.

ANTI-DIMMING COMPOSITIONS.

ATTENTION is called to the contribution of P. W. Carleton to the December, 1919, issue of the *Journal of Industrial and Engineering Chemistry* on the subject of anti-dimming compositions, primarily for use in gas masks. There is also a contribution from the Chemical Laboratory of Oberlin College on the same subject in that number of the journal. It seems reasonable to expect that some commercial applications may be made of the principles which have been established and the formulae which have been devised.

Inasmuch as good vision is one of the important properties of the gas mask, it early became apparent that some device must be invented which would prevent the rapid dimming of the various types of eye-pieces used in gas masks. A considerable number of people worked upon this problem.

Some of the requirements which a satisfactory anti-dimming composition must fill are: "It must be soluble in water and reduce the surface tension of water so that moisture will not form drops on the lens. It must be easy to apply. Its method of application must be fool-proof, so that if possible an unsuccessful application will be impossible. One application must last a long time, several hours of consecutive use. It must function properly several days after its application. It should be put up in a convenient outfit which should have but few parts and should not be fit for other uses. Obviously the unit should be cheap." It is interesting to note that one of the first anti-dimming compounds was in the form of a stick which was put up in a little tin box, strong and well made, and this holder became so attractive as a receptacle for matches or cigarettes that without thought of future safety, the sticks were discarded and the holders put to new uses.

A variety of formulae were used, the stick to which reference has been made having a formula: 100 parts 85 per cent turkey red oil; 15 parts caustic soda; 5 parts water glass; and 5 parts paraffin oil. This product contained from 10 to 20 per cent of moisture. Later sodium carbonate was substituted for the caustic soda because of the harmful effect of the caustic upon the hands.

Another formula, in addition to the ingredients above named, added 23 parts of glycerine and required a different method of application. The surfaces of the eye-piece were wiped clean, and after breathing on the inside surfaces, a very small amount of the composition was applied, rubbed in thoroughly with the finger, and then gently polished with a cloth.

The work at Oberlin was undertaken at the suggestion of the National Research Council, and involved an elaborate study of some nine points. These were: Studies of the sul-

phonated glycerides of saturated and unsaturated fatty acids, as well as sulphonated fatty acids; of the relative merits of the different alkali salts of the sulphonated fats; of soaps of the saturated and unsaturated fatty acids; of Twitchell's sulpho derivatives; of the effect of excess constituents in preparing anti-dimming sticks; the relation of surface tension lowering to the desired anti-dimming effect; the influence of solubility on the lasting power of anti-dimming sticks; the effect of varying thickness of the anti-dimming film, and more rapid and accurate methods of testing.

The results obtained from these studies appear in the original article and it is pointed out that soaps in general are improved by the addition of a few per cent of glycerol, 10-15 per cent of alkali, and a small quantity of marine oil. The sodium silicate or water glass serves well as a binder. The soaps from a variety of vegetable oils all show excellent film-forming properties, and the final recommendation concerns anti-dimming preparations made from sulphonated rape seed oil and sulphonated cotton seed oil.

WHAT A FLOUR CHEMIST DOES.

IN the *Chicago Bulletin* which is issued by the Chicago Section of the American Chemical Society, we find in Number 8, Volume 6, an outline of some of the things a chemist who specializes in flour is called upon to do. The greatest emphasis is placed on baking tests. The loaves are allowed to rise to the greatest possible extent, since the size of the loaves gives important information as to the so-called strength of the flour. As a result, the loaves are of very coarse grain.

Many analyses must be made and certain facts have been determined, although there remains much research to establish new data. To quote from the article mentioned:

"*Moisture.* Moisture should not exceed 13 per cent. Flour with excessive moisture is more likely to become sour or musty, especially in warm weather or in unventilated or damp storage.

"*Acidity.* The percentage of acidity (calculated as lactic acid) is an approximate measure of the soundness and keeping quality, or in the case of flours bleached by chlorin-containing gases, of the amount of bleaching given. A small increase in the amount of acidity present might not render it unfit for use, but indicates a somewhat diminished ability to keep well if storage conditions are adverse.

"*Soluble Carbohydrates.* Soluble carbohydrates (sugars, dextrins, etc.), are the fermentable materials and in sound flours do not usually exceed 6 per cent. Flours made from sprouted wheat have increased amounts of soluble carbohydrates. If soluble carbohydrates are present in less amount than about 1.2 per cent, the loaf made will usually have a pale crust or require extra amounts of sugar in order to take a normal brown.

"*Gluten.* Low grade flours have more gluten than higher grade flours made from the same wheats, though they are usually of inferior quality. Soft glutens lack the ability to spring and will not stand a long fermentation with yeast. Flours high in gluten of elastic quality require longer or more vigorous fermentation than those with less gluten.

"*The Baking Test.* The test loaf is made by a special formula and baked in an expansion test pan designed to give the gas-filled dough maximum opportunity to expand and to exhibit its stability. It is not the intention to produce a loaf of the same qualities, close-grained texture and shape produced commercially, but to bring out and emphasize the individual merit or demerit of the flour. Test loaves having a volume of more than 180 cubic inches (2,950 cubic centimeters) are to be considered strong and satisfactory for bread making and those of 200 cubic inches or more (3,277 cubic centimeters) as o superior strength. A variation up to 5 or 6 cubic inches is of little significance, owing to the complexity of yeast fermentation processes and the fact that yeast is a vital organism variable to some degree in strength.

"*Volume.* The volume indicates the ability of the flour to expand, hold up well and give a light, well-piled loaf, and if necessary stand a reasonable amount of unfavorable treatment.

"*Weight of Loaf.* The weight of loaf is taken as it comes from the oven and shows the ability of the flour to hold the absorbed water and make a good bread yield to the barrel of flour. Yields are strictly comparative, but due allowance must be made for the continuous shrinkage in weight of loaf from the time of weighing. The water used shows the actual absorbing and retaining capacity of the flour in baking. Due consideration must be given to the moisture content and age of the flour, freshly milled flours usually having less absorption and bread yielding ability than older flours."

THE WORK OF THE FOOD CHEMIST.

IN *Chemical Age* for December 10th there is an interesting discussion by L. M. Tolman concerning the "Work of the Chemist in the Food Industries." As Dr. Tolman points out, a survey of the last twenty years in the development of chemistry and scientific control in the food industry, would indicate that the most important work has been accomplished along the lines of preventing spoilage and decay. A great deal has been learned regarding the cause of spoilage and quickly following that work has come the development of methods to remove the cause. Much of this work has been done in the Bureau of Chemistry, as well as in the laboratories of those who prepare food on a large scale and in the universities.

At the present time the Bureau of Chemistry numbers among its research problems the following investigations with respect to food; the cause of decay in poultry and eggs; the handling and care of broken eggs, first to determine their fitness for food, and second to improve methods of freezing, drying and storage; a study of the methods for handling poultry as regards cooling, chilling, packing, transportation and storage until they are marketed; a general survey of the questions relating to the deterioration of food products from the time they leave the farm until they reach the consumer. There is a similar investigation with reference to fish and the effect of low temperatures during the different periods of storage. Special attention is being directed toward the sardine industry and the sanitary and hygienic methods to be employed in packing.

The National Canners' Association laboratory has been actively engaged in studies upon the types of micro organisms responsible for spoilage in canned foods in an effort to develop satisfactory methods for complete sterilization that will leave the contents of the can attractive in appearance.

There has been a vast amount of work done upon milk to the end that notwithstanding the difficulties inherent in our modern long-distance transportation of this food, safe milk may be delivered in our large cities. Just imagine for a moment what would be involved if a city had to depend upon the distribution system of the small town or upon the primitive method in vogue in parts of the old world where the milk goat is driven to the door and milked!

It may be news to some that the frying of doughnuts is an exact science and as Dr. Tolman says, "To give the best results it must be carried out at a definite temperature for each individual kind of fat, and with the different methods of making the dough. The working out of these conditions has to be done with much more exactness than is ordinarily done in the kitchen. So that we find the large producers of lards, cooking oils and compounds first work out the best methods of using their products in pies, cakes and bread before they send out their directions for using. In this way we find the chemical laboratory expanding its work so as to include the trained domestic science worker."

The problem of the food chemist is frequently very complex. Many industries have actually begun in small kitchens with the producers personally marketing their product. To maintain the same characteristics in such products when pre-

pared on a commercial scale is sometimes difficult, for foods must be not only nourishing and attractive in taste, but must maintain an appetizing appearance. Flavor is a very delicate quality and when once the public taste has been cultivated all precautions must be taken to maintain the taste unimpaired.

Just as the prevention of spoilage has been the outstanding feature of the last twenty years, so Dr. Tolman predicts that during the next period we may properly expect unusual developments due to recent work with those indefinite substances called vitamines, the influence of which upon body growth and maintenance has been proven so conclusively in experiments not only upon laboratory animals but in, many cases, upon human beings.

SCIENTIFIC INSTRUMENTS.

THE United States Tariff Commission has compiled information concerning scientific instruments for the use of the Committee on Ways and Means of the House of Representatives, and in this is brought together considerable information of interest to the chemist. For example, the many paragraphs under which scientific instruments are mentioned in the Tariff Act of 1913 are brought together in one place where a comparison of rates of duty on the different materials of interest to the laboratory can be made. The articles included under the term scientific instruments are very diverse. Such instruments are characterized by a high degree of sensitiveness and the dependability with which they serve their various purposes. They are instruments for the measurement of weight, volume, length, heat, temperature, light, color, and time. A great many instruments are electrical, either because of their employment in relation to electrical phenomena, or by reason of the use of electricity in the determination of other phenomena. The continued application of scientific methods to industry has developed a new and extended demand for scientific instruments which were formerly little known outside the laboratory of the student. We now have many kinds of engineering, physical, chemical, and medical instruments.

In the manufacture of such instruments the major portion of the raw material is metal and glass but porcelain, wood, rubber, different sorts of insulating materials, quartz, feldspar, and calcite may also be mentioned. The methods of manufacture employed in the United States do not differ materially from those abroad, but it is evident to many that if the industry can be developed to the point where quantity production can be undertaken, our manufacturers can then provide the necessary tools and in some cases automatic devices that will permit the production of high-grade instruments on the American system, which should greatly reduce the cost of manufacture, now a handicap in competition for both domestic and foreign custom. For example, there has been no such opportunity to standardize and to put the scientific instrument industry on a great producing basis as has been the case with automobiles, sewing machines, typewriters, and similar apparatus.

The census indicates that there were 197 companies, with a total capital of thirteen million dollars, as producers of scientific instruments, excluding medical and surgical instruments, in 1914. Seventy per cent of these establishments are to be found in New York, Illinois, Pennsylvania and Massachusetts.

The conditions of war have changed some classes of instruments from the exclusively imported to the exported side of the books and scientists generally, as well as the manufacturers, are now concerned with the question of keeping our scientific instrument industry on a basis that will provide domestic needs and also permit exportation. To do this without placing an undue burden upon educational institutions is one phase of the problem, for notwithstanding the greatly increased cost of production abroad, it still costs more to make devices of this kind in the United States, although in some instances, notably chemical glass ware, the quality of our American manufactured material is better than that which heretofore came from across the pond.

QUEBRACHO.

THE Latin American Division of the Bureau of Foreign and Domestic Commerce has recently reported upon the quebracho industry as it is found in South America, Argentina and Paraguay being the two most important countries. The following is abstracted from that report:

Quebracho is one of the natural monopolies of South America, just as potash has been a natural monopoly of Germany and jute of India. It is a distinctly South American wood, but is confined to a region of some 300,000 square miles near the central part of the continent, particularly northern Argentina and western Paraguay. In some of the other countries, notably Bolivia, Brazil and Uraguay, these trees are to be found scattered through the forests, but this distribution greatly raises the cost of operations. It is believed that the present rate of cutting is less than the annual growth, so that there is no immediate danger of exhausting the supply of raw material.

The first appearance of quebracho wood was at the Paris Exposition in 1867 soon after which it began to be used for tanning purposes in Europe. It has been prominent as an important commercial commodity for only thirty years, the exports in 1887 of logs from Argentina being valued at 172,700 pesos, with a high water mark in 1911 when the value was 6,897,000 pesos. The total value exported from South America in 1916 was 19,663,000 pesos. The first trade was established in quebracho logs but in the last twenty-five years the industry of preparing the extract has been built up in South America and is now in a flourishing condition. Notwithstanding this activity, there has continued to be an extensive exportation of logs, particularly to Europe and as the wood is very heavy, it is one of the curious features of the trade that this shipment of logs 6 or 7 thousand miles should be maintained, especially in view of the fact that the expansion of the extract industry in South America could easily provide the requirements of American and European tanners. The answer seems to lie in the fact that certain tanners find it desirable to make themselves independent of the extract producers and in the fact that the quebracho wood contains such a large percentage of tannin that the loss involved in shipping the logs is not great. They are usually carried in sailing vessels at low cost and besides this, the increased skill and experience of the operators and the more scientific methods employed in certain foreign countries made it possible to import the logs and then sell the extract at prices lower than those in Argentina. Before the war Germany, for example, exported 20,000 tons of extract yearly at prices less than those of the extract delivered in Buenos Aires.

In obtaining the extract from the wood the customary method is to reduce the logs to chips by the use of revolving cylinders faced with sharp knives, after which these chips are either placed in vats of water and boiled or are digested in closed copper containers with the use of steam. The resulting liquid, which is very concentrated if prepared by the second method, is cooled, then allowed to stand a sufficient time for settling, or precipitation is caused by the use of chemicals. This process also tends to decolorize the liquid. Now the clear liquid is evaporated until the moisture has been reduced to 50 to 60 per cent if it is to be shipped in liquid form, or to 20 to 25 per cent when it solidifies upon cooling. Approximately 23 per cent of the weight of the wood is represented by the extract.

While quebracho is not indispensable to the tanning industry, it is a very desirable reagent, for it does its work very rapidly, producing results in a few days which are secured by other tanning materials in a period of weeks or months. The importance of quebracho in the war was largely due to this rapid action, and when the demand for greatly increased supplies of leather is not so imperative as it has been, other tanning materials can be used if there is a cost advantage.

QUICK-HARDENING CONCRETE.

P. H. BATES of the Pittsburgh branch of the Bureau of Standards, has reported the results of some of his researches on cements capable of producing quick-hardening concrete. These materials are prepared in a manner similar to the method employed in making ordinary Portland cement, but their composition differs considerably in that they are composed principally of lime and aluminum. These calcium aluminates are very high in alumina and while they do not have a very rapid initial set, they do harden quickly and therefore produce high strength within a short space of time. For example, one of the mixtures has a strength of 3,145 pounds per square inch for a 1:6 mixture, tested in the form of a six by twelve-inch cylinder at the end of twenty-four hours, 6,100 pounds per square inch at the end of seven days, and 8,220 pounds per square inch at the end of one year.

There are also a number of tests reported with concrete in which "Sorel cement" was employed. These cements are prepared from light calcium magnesium and magnesium chloride solution and in twenty-four hours such a cement develops strength nearly equal to that shown at the end of seven days by a similar concrete in which Portland cement is employed.

Such cements cannot be used where the resulting concrete is expected to withstand prolonged action of water, but they do commend themselves for certain special uses where a concrete must not only harden in a brief space of time, but also develop high strength. The Sorel cement concretes cannot be frozen and temperatures below freezing, while retarding setting, do not interfere with the action of the cement and no special precautions need be taken in protecting the material when used at low temperatures. The preparation of foundations for guns is but one of the many examples of the special uses for which such materials can be employed and as such an amount of moisture as is usually present in the air does not materially affect the strength, it appears that other considerations than quick-hardening may make them very desirable.

In the case of the Sorel cement concrete, hardening takes place as the result of the reaction between the magnesium chloride and the magnesium oxide. Hence the importance of having the correct proportion between these two magnesium compounds in preparing the cement and concrete. In the case of the calcium aluminates, it appears that hydrated alumina, and calcium, when formed under the proper conditions, constitutes the greater part of the binding material of the compounds. The higher the alumina content in the aluminates, the slower will be the action with water forming the hydrated alumina, and consequently the slower will be the time of setting.

The results of Mr. Bates' work were reported before the American Society of Testing Materials and will be found in the Proceedings for 1919.

SMELTER WASTES.

IN many instances so-called industrial wastes can be recovered, but there is frequently the question of what to do with them. Manufacturers can hardly be expected to go to the expense of recovering large quantities of material for which there is but a limited demand and apparently small prospect for developing new uses. It has been pointed out that if all the arsenic was to be recovered from smelter fumes, the mere storage of this poison would become a considerable problem. The same has been true of the sulphur dioxide from the stack gases of smelters which are naturally located at points at considerable distances from possible markets.

In the December issue of the *Journal of Industrial and Engineering Chemistry* it is noted that the Forest Products Laboratory has suggested the possibility of utilizing liquid sulphur dioxide which could be prepared from these stack gases for the manufacture of sulphite acid for the paper industry. Liquid sulphur dioxide would not present a difficult transportation problem and possesses many advantages over sulphur for the purpose mentioned. For example, this liquid sulphur dioxide from the smelter product is free from all foreign material with the exception of a very small percentage of moisture. It could be produced in quantities exceeding the demands of the sulphite industry and its use would conserve sulphur and sulphur-bearing materials now employed.

The paper industry has also been suggested as a possible outlet for the excess chlorine gas sometimes produced in the manufacture of sodium hydroxide from brine solutions. Certain mills have already installed their own bleach plants, finding it more satisfactory to produce chlorine products at the mill than to transport them, but there are still a number of mills which might find it profitable to experiment with liquid chlorine in preference to the bleach with which they are so familiar.

FIRE-PROOFED TIMBER.

NOTWITHSTANDING extensive uses of metals, concrete, and other non-inflammable building materials, a vast quantity of wood continues to be used, and it is still important to devise methods for reducing the fire risk. An English company has announced the perfection of a process which consists in first removing the air, moisture and sap under heat and vacuum treatment, and then impregnating the wood with a mixture of non-inflammable chemical solutions which replace the materials previously removed. The final treatment dries the wood, causing the chemicals to crystallize and then these crystals to form a coating which excludes oxygen, thus rendering ignition an impossibility. It is claimed that the higher the temperature the greater the expansion of these crystals throughout the wood, so that while excessive temperatures may cause charring, there is no flame. It is also stated that no detrimental effects are imparted by this treatment, that the wood can be nailed or have screws inserted, finished by any of the approved processes, resists warping and deterioration as well as changes due to atmospheric conditions. The figures as to costs have not been published in detail, but no doubt the cost of treatment is not excessive considering the many resultant advantages.

PRICE OF GERMAN CHEMICALS IN GERMANY.

ACCORDING to a recent issue of the *Leather World*, an English publication, the prices of chemicals in Germany and especially those used in the production of leather, have risen enormously. This may be illuminating to a few Americans who have been longing for the return of the days when it will be possible for them to again import German supplies at the old figures. The rise in price is due partly to the central offices which have increased some of the prices by fifty and sixty per cent, and it is impossible to ascertain prices far in advance, as they vary within wide limits according to the buyers and sellers in different districts. One kilo of soda, for example, is now five marks in Germany as against eight to ten pfennigs in pre-war days, and there seems to be little, if any, prospect for early improvement in the situation.

INSULATING VARNISHES.

THE *Electrical World* publishes a note accompanied by a table giving the characteristics, solvents, and drying time of several varnishes suitable for insulating material. Dielectric resistance is said to increase directly with the length of baking or time required for drying, and it has been found that the slow drying varnish imparts the highest degree of insulation, producing a flexible, tough film which has high mechanical strength and considerable durability. Black varnishes seem to produce better insulation than clear varnishes of the same class. Of course, varnishes should not crystallize under prolonged vibration.

PAPER BOTTLES.

ALTHOUGH bottles of glass have always seemed rather cheap, those who are looking ahead begin to realize that the cost of fuel may some time soon so greatly increase the cost of glass that other types of containers must be considered. The desirability of a one-time or single service container is also obvious and considerable research has therefore been done upon a paper or wood fibre bottle.

Many devices have been invented, some of which depend upon forming the wood fibre on the outside of a collapsible mold through the use of suction. The raw material in most cases has been the same—pulp, or waste paper reduced to a pulp, forms the basis of most of it, and the remaining problem is that of proofing the container against the materials which are to be placed in it, having the proper consideration for low cost and an odorless, tasteless material.

A recent invention provides for blowing the pulp into the desired shape and drying the container by the use of superheated steam or air. It is stated that with the automatic machinery which has been developed one dollar's worth of ground wood pulp will produce 2,133 one-pint containers at a total manufacturing cost less than that involved in merely gathering and washing the usual pint milk bottle.

ANALYSIS OF GERMAN AIRCRAFT FUEL.

IN a recent paper read before the French Academy of Sciences particulars are given regarding the composition of the aviation gasoline employed by Germany. Analyses taken of twenty-two separate samples have given the following result: Aromatic carbons, 10 per cent; saturated cyclic carbons, 10 per cent; acyclic carbons, 56 per cent.—Abstracted by *The Technical Review* from *La Nature*, Nov. 22, 1919.

FURTHER DYE DEVELOPMENTS.

ATTENTION is again called to the dye question and particularly to the hearings which have been held before the Senate Committee in connection with the Longworth Bill, passed by the House and now before the upper body. The question which has been so frequently asked by those opposed to the licensing system, namely: "Why did Dr. Herty fail to obtain the dyes for which he journeyed to France?" was fully answered in the testimony of the Alien Property Custodian, F. P. Garvan, who was able to produce a copy of the cablegram sent by German agents in this country to von Weinberg, from whom Dr. Herty had received certain options. The cablegram in question stated: "We fully expect modification Government regulation which will permit us to confirm our orders. This will enable you to maintain your position that all goods to this country outside reparation goods should come to us." Five days after that cablegram was sent von Weinberg cabled: "Sorry we cannot renew your option." Shortly after this, information came to light making it clear, as Mr. Garvan pointed out, that it was not a question as to whether we shall have a license system, but merely whether this license system shall be an American one or one controlled by Germany. The German agents realized the damage that had been done by the cablegram exchange and later on von Weinberg again cabled renewing the options.

The hearing in question was one of greatest interest and a mass of testimony was introduced to show the importance of the dye industry to the medical profession through the accompanying research work on organic compounds, to biologists, and as an agency for defense due to the ease with which plant and experience can be turned to munition production in time of need. It is difficult to see how anyone can seriously oppose the steps needed to insure these advantages for us.

Research Work of the United States Bureau of Standards

Notes Specially Prepared for the SCIENTIFIC AMERICAN MONTHLY

THE WORK OF THE BUREAU OF STANDARDS IN TESTING AIRPLANE ENGINES.

THE difficulties which surround the successful testing of an engine designed for service in an air craft are perhaps not generally appreciated. The successful testing of stationary steam or gas engines presents no particular difficulties, and even in the case of locomotives, laboratory dynamometer tests have been carried out with success for many years. The peculiar conditions under which aircraft engines are called upon to operate are the main causes of the difficulty in carrying out successful laboratory investigations. Such engines do not ordinarily work under the conditions encountered near the surface of the earth but perform most of their duty at altitudes ranging from a few hundred to 30,000 feet or more. Atmospheric pressures and temperatures are very different at high altitudes from those existing at the earth's surface, and both have a great influence on the operation of an internal combustion engine. The amount of explosive charge which the engine is capable of drawing into its cylinders varies with the density of the air, and this, of course, changes with the altitude. Temperature is also a controlling factor, and besides affecting the quantity of the charge drawn into the cylinder, also produces numerous other variations in the operation of the engine, such as those brought about by the reduction in temperature of the circulating water, the oil, etc.

Over two years ago, it was decided that an extensive investigation of aircraft engines under altitude conditions ought to be carried out, and in coöperation with the National Advisory Committee for Aeronautics, the Bureau of Standards constructed what has since become known as the "Altitude Laboratory." Briefly, this consists of a small concrete room constructed with walls of sufficient thickness and so reinforced as to resist a considerable pressure from without. The chamber is provided with two large doors on opposite sides, arranged to close upon rubber gaskets, so that they are practically air-tight when shut. Within this chamber a stand is placed, so arranged that upon it can readily be mounted any ordinary type of aircraft engine. Means are likewise provided for withdrawing the air from the interior of the chamber, and also the exhaust gases from the engine by means of a vacuum pump. The engine is connected through a flexible coupling with a shaft passing through the wall of the chamber to an electric dynamometer mounted outside the latter. The power of the engine is thus absorbed and may be readily measured.

The air which supplies the carbureter first passes over a bank of refrigerating coils placed above the altitude chamber and its temperature is thus reduced to a point approximating that which would be met at the altitude under which the test is to be conducted. Since by means of the refrigerating plant alone, the temperature cannot be controlled with sufficient accuracy, electrical heating grids are likewise mounted in the air pasage and thus the air's temperature may be held substantially at the figure desired. Similar cooling coils are installed within the chamber itself and fans driven by electric motors circulate this air past the engine, thus simulating the

conditions of an actual flight. As before mentioned, the exhaust gases from the engine are withdrawn by means of a vacuum pump. They are first cooled, however, by injecting water into the exhaust pipe at some distance beyond the engine connection. This water is again separated from the gases before they enter the pump.

The equipment for measuring conditions surrounding the operation of the engine is unusually complete. Thermocouples have been located at all points where it is of importance to determine temperatures, and by means of a manometer board the pressures on both the intake and exhaust sides of the engine, as well as within the chamber, may readily be determined. Weighing tanks are provided for the fuel and a meter is placed upon the air inlet of the carbureter to determine the air flow to the engine. Since it is possible to determine with ease the total heat units in any given fuel, and since the heat equivalent of the engine's brake horsepower may be likewise calculated, it is possible to state with accuracy the brake thermal efficiency of any type of internal combustion engine.

The heat losses which occur are also easily measured, since the total amount of water passing through the jackets and its rise in temperature are recorded as well as the amount of water used to cool the exhaust and the change in its temperature. The only undetermined heat loss is that due to radiation of the sufaces of the engine, but this is known to be extremely small.

This plant has enabled the Bureau to make observations on aircraft engines under conditions closely approximating those met with in actual flight, and yet without any great amount of difficulty and surrounded with all the necessary laboratory appliances. Investigations have been conducted to determine the relative merits of various types of airplane fuels and the work in the altitude laboratory largely influenced the drawing up of specifications for the so-called "fighting grade" of gasoline used by our Air Service during the war. Many investigations have been conducted on aircraft engines and their appliances and much of the development work on the Liberty motor was carried out in the altitude laboratory.

The work above described has almost an equal importance in peace times, owing to the ever-increasing number of air craft in use, and because of the fact that under ordinary conditions economy in fuel and durability during long periods of service is of even greater importance than in war.

The original altitude laboratory consisted of a single chamber as described above, housed in a temporary wood and stucco building. This has now been replaced by two chambers forming a part of the equipment of the new dynamometer laboratory of the Bureau of Standards. The two chambers are so connected that they may be used separately or together, that is, both sets of pumping equipment may be used to withdraw the air and gases from one of the chambers, thus allowing the testing of very large engines.

It is expected that a very complete program of investigation will be carried on and it is believed that the work will be of the greatest importance, not only to the aeronautic industries, but to all those interested in the fundamentals connected with the performance of internal combustion engines.

INVESTIGATION TO DETERMINE THE HEATING OF CAR WHEELS CAUSED BY THE BRAKE SHOES.

THE type of wheel in very general use under the freight cars in the United States is made of chilled cast iron. This style of wheel has been in use with general satisfaction for over half a century. Failures of wheels of this type are comparatively rare, but it has been noted that on railroads having long grades, quite a large number of derailments have occurred at the bottom of these inclines, apparently due to failure of one or more car wheels. After extensive study of these accidents, it has been determined that the failure of the wheels is caused by heating due to the prolonged application of the brake shoes on the descending grade. This heating is sufficient to set up extremely high stresses within the wheel which ultimately cause cracking and failure.

In order to determine the exact temperature in different portions of the wheel, after prolonged heating of the rim, the Bureau has instituted a complete investigation of this subject. It is obvious that such measurements cannot readily be made upon a wheel in service, and considerable ingenuity has been shown in perfecting a laboratory apparatus capable of producing conditions analogous to those met with on the road. The wheel is mounted in a vertical position and surrounded by electrical resistance coils insulated from but setting close against the rim of the wheel. Holes are drilled in the wheel at all points at which it is desired to obtain temperature measurements and into these openings thermocouples are inserted. The wheel can thus be heated to any desired temperature at the rim, and the corresponding temperatures at other portions easily read. Quite a number of wheels have already been tested and others are being submitted from time to time by parties interested in this work.

FLAT SLAB INVESTIGATION.

THE preliminary work on the testing of the concrete floor, mentioned in the last issue, is being carried forward rapidly. Beginning on November 26, a series of readings of deformation in the steel and concrete were taken three times each day. A total of eighteen gage lines were read each time, these lines being well distributed over the under side of the slab. This work was continued until December 13. The particular object of these special readings was to obtain important information regarding the changes in the stresses due to weather conditions which were very variable at that time. At the time of this writing, the load tests are about to be commenced and in a few days it is expected that the action of the structure can be predicted. The loading material in this case will consist of stacked brick 5 x 8 x 4½ inches in size. The first application of load will consist of one layer of these bricks over all parts of the slab.

A SUBSTITUTE FOR JUTE BURLAP FOR SAND BAGS USED IN MILITARY WORK.

PRELIMINARY laboratory tests have been completed in the investigation of substitutes for jute burlap for sand bags, such as are used by the Army. It has been shown that paper does not equal burlap in tensile or bursting strength, but, nevertheless, it is felt that paper suitably made up into bags may be of value for this purpose. Further tests are to be made on four types of paper, as well as on burlap and cotton fabrics, and all these materials will be subjected to weathering tests. Bags will be obtained, made up of these materials, and will be given laboratory tests and also tests under field conditions.

DETERIORATION IN THE STRENGTH OF PAPER AFTER STORAGE.

As a result of tests on approximately 150 samples of paper, stored since March, 1909, it is noticed that bonds and ledgers containing 100 per cent rag did not deteriorate in bursting strength as much as printing, writing, and similar papers containing wood pulp. The loss in bursting strength for the first class of papers tested was 11.9 per cent, while the bursting strength for the second class was 20.4 per cent less than when tested in 1909.

While these conclusions have been derived from tests on nearly 150 samples, as above noted, a still larger number of additional samples will be tested soon, and the results studied to determine, if possible the cause and amount of the deterioration of paper in storage.